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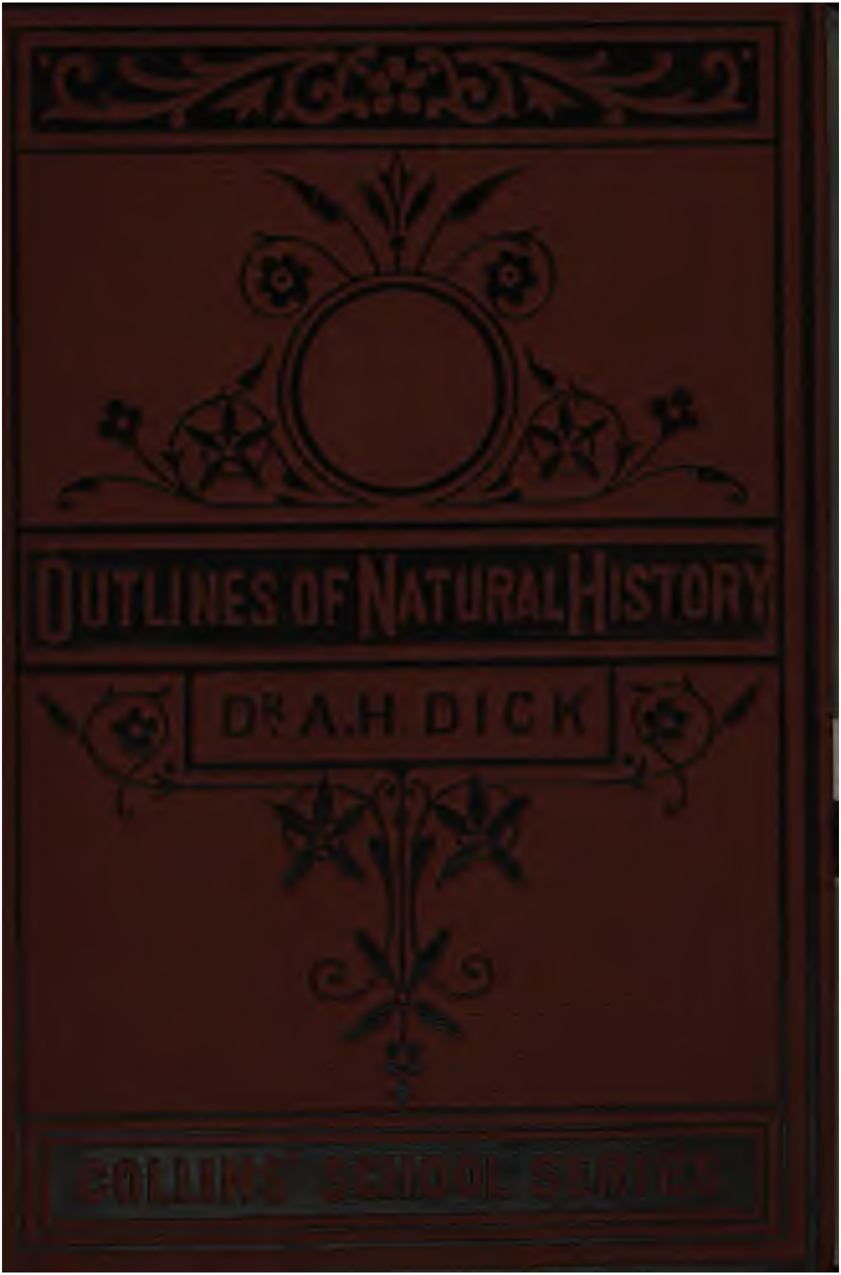

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OF

NATURAL HISTORY.

BY

A. H. DICK, D.Sc. (EDIN)., M.A., LL.B. (LOND).

With 47 Illustrations.

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PREFACE.

To give a clear, connected, and pleasantly readable account of some of the most interesting and important facts regarding minerals, animals, and vegetables; to state only such things concerning them as may be found in works of admitted authority; to do so without the use of hard technical terms; to make plain the things meant by these terms by using ordinary English substitutes for them in the text, and giving as foot-notes those that occur most frequently in more complete works on the subject; to be short, omitting details, and yet to omit nothing that shall conduce to a fair knowledge of the outlines of Natural History; to state very briefly, therefore, a large number of facts, avoiding indistinctness on the one hand, and the making of a mere catalogue on the other; to make a reading book, which, though short, is so arranged that a teacher may easily expand its teachings without departing from its order, by giving additional illustrative facts and anecdotes verbally, and which, even though unaided by such expansion, may be not uninteresting reading; to afford a limited and definite amount of instruction in such a manner that the young, having gone through it, may wish for more, and shall have attained to a fair state of preparation for the study of more formal and systematic books on Natural Science; to give some help, even without further study, to the understanding of phrases and discussions which are at present turning up often in current literature; to assist the youthful scholar in beginning for himself a course of observations upon the natural objects around him, and to enable him at least to look with less of mere gaping wonder and more of intelligence and interest into the glass cases and drawers of a school or district museum;—these are the objects of the following pages.

A. H. DICK.

August, 1874.

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OUTLINES OF NATURAL HISTORY

PART I.

THE MINERAL KINGDOM.

CHAPTER I.

THE CENTRAL FIRE.

Any one who has seen ice become water by means of heat, and water, when the heat is increased, become steam and spread itself out and disappear in the air, can imagine what would happen were an intense and ever-increasing heat brought to act upon the whole world. Suppose that from any cause, no matter what, the heat of the whole air and ground of the world were to become as great as that of boiling water. All the waters of the rivers, and lakes, and seas would boil and pass off in steam, and the animals and vegetables on the earth would die. Suppose this heat to become three times greater, then metals would begin to melt; and zinc, lead, and tin would flow in streams. Let the heat become greater still; go on supposing an increase of it to any extent, and think what must happen. First, everything solid would become red-hot, then melt, then boil, then pass off as vapour, and the vapour would spread itself through space far away beyond the limits which now bound our world—the great globe would cease to exist, leaving not even a wreck behind.

Now, things being in this state, reverse the supposition. Let cold begin to act, and act ever more and more. The widely-scattered atoms of our former world would begin to condense, or gather themselves together again. They would first form thick vapours; these would become liquid as the cold increased; and, at length, a cake or crust of solid matter would form on the outside of the boiling liquid. This crust would thicken more and more as the cooling went on; and, in the end, we should have our old world, or at least the matter of it over again; a hard solid crust shutting in a central mass of fiery substance.

In the study of science one is permitted to suppose anything, if he will but remember, and acknowledge to others that he only makes suppositions; will give reasons to show that what he supposes may be true; and be ready at any time to give up his suppositions when facts go against them. The last of these two suppositions, namely, the gradual cooling of the world from a state of intense heat, is often made by those who wish to form to themselves a notion of how the rocks and rivers, mountains and plains of the world have been brought to exist as they are. They find that such a supposition—a hypothesis, as it is called—helps them to arrange a large number of facts together, and, as it were, to form a chain of things known; of which chain the supposed fact of a world gradually cooling forms one end-link.

The study of the changes which appear to have gone on in the crust of the earth so formed is called Geology. When the properties of the materials of which the crust is formed are studied, the science, or kind of knowledge sought is called Mineralogy. Neither Geology nor Mineralogy concern themselves with the beings that live, or have lived, upon the earth, except in so far as these help to an understanding of the changes or materials of the earth's crust. The study of plants, which form one great division of living things, is called Botany; that of animals is called Zoology. These four sciences form, when taken together, the branch of knowledge called Natural History.

Now let us see by what kind of reasonings men have felt themselves justified in supposing that the whole world was once a mass of molten matter. In all sciences which are really sciences, men look well at the things which can be directly seen and known, and try from them to find out the things which are yet unseen and unknown. The world, as it is, is three-fourths covered by water.

The other fourth forms what we call the continents and islands. Over the most of the surface of these continents and islands is spread a thin layer of soil upon which plants grow, called vegetable soil. Beneath this we find large masses of solid limestone, sandstone, clay, and other things, which, whether hard or soft, in united lumps or separate grains, are called by geologists rocks. And by going down pits, travelling along river banks or cuttings of railways, we see that the most of the different kinds of rocks are piled one upon another in layers or beds, to which the name strata is given, and the rocks themselves are said to be stratified. We see, too, that all these stratified rocks rest upon rocks which do not range themselves in layers, and present quite a different appearance from the others. Of this kind, the rock best known is called granite. It is that kind of grainy stone of which the hardest pavements are made, and the best bridges are built, and which one may often see beautifully polished, forming pillars and tombstones. In some parts of the world the stratified rocks are wanting, and the granite stands bare; and everywhere, if it cannot be seen, men are sure to find some form of it when they dig deep enough down through the layered rocks.

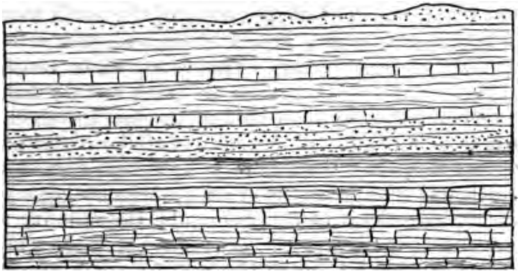

Fig. 1.—Stratified Rocks.

Then again, when we descend into mines, we find that the heat is greater the deeper we go down. The deepest mines are the hottest, and their heat does not change with the seasons; it is the same summer and winter.

Judging from this increasing heat, men reason that at the depth of twenty-five miles under ground even the hardest rocks would melt, and at the depth of a hundred and fifty they would go off in vapour. This heat underground is found in every country; in the silver mines of sunny Mexico, in those of chill Siberia. In some parts of Siberia the ground is frozen all the year through, and the water which sinks into it a few feet becomes ice. Only in summer that which lies very near the top becomes liquid. But when you dig below the ice-layer, even in winter, you come at a depth of about a hundred yards to flowing water. It is clear that the heat which makes it liquid does not come from the sun, or from any source outside of the earth, for then the ice near the surface of the ground would also be melted; and the conclusion that men come to is, that this is the heat which yet remains from that time when all the earth was a boiling liquid mass.

The world, as we know, is not quite round. It is flatter at the poles than at the equator. Now, this flattened shape is exactly that which a round mass revolving would take if it were in a liquid state. Experiments can be made which show that a liquid globe revolving quickly flattens itself so. The shape, then, of the earth seems to prove that it was once a liquid globe, although it is now covered with a rocky crust. This crust, which cannot, as we have seen, be thicker than five and twenty miles, is no more compared to the whole earth than the shell is to the whole of an egg. If this thin shell be round a mass of central fire, why then, it may be asked, does this fire not burn us? Because the crust is rock, not metal, and does not suffer the heat to pass easily through it. In a furnace full of boiling metal, ten times hotter than boiling water, a few bricks keep all the heat in—and we can lay our hands easily enough on them. This central fire, owing to the nature of the rocky crust, does not, in fact, add to the heat which the sun gives to the surface, more than one three hundredth part of the heat required to make melting ice into boiling water.

Let us see in what other ways the central heat shows itself at the surface of the earth. It shows itself for one thing in thermal springs; that is, in springs of water warmer than the ground from which they flow. There are many such in France and Germany, some nearly boiling. The well-known geysers of Iceland throw out jets of boiling water at times as high as 200 feet. There are other places in the world where jets of steam hotter, of course, than boiling water are thrown out.

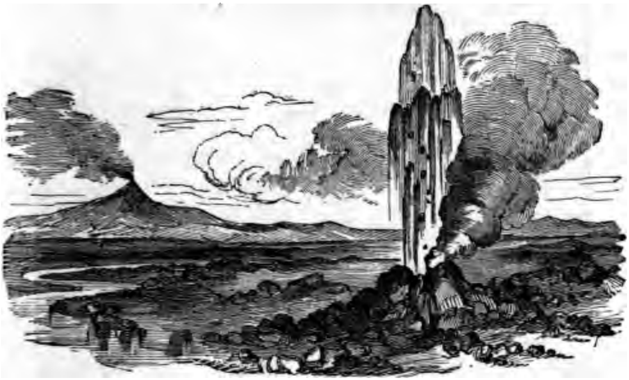

Fig. 2.—GREAT GEYSER.

But the effects of the central heat of the earth are still more strikingly seen in volcanic eruptions. A volcano is a burning mountain. From an opening in the bottom of a cup-like hollow called the crater, on the top of such a mountain, smoke is always rising, often flames; and at times red-hot molten material called lava flows from it. Each of these mountains is, in fact, a chimney, the foot of which is in the hot central depth, and the top is the opening in the crater. Mounts Vesuvius and Etna are the best known, because they are in countries near us; but these vent holes for the inner fires of the earth are found in many parts of its surface; rising often in solitary mountain peaks—sometimes forming part of mountain chains. A long chain of them may be traced northwards along the western shores of North and South America, and then southwards on the eastern shores of Asia, with branches into Iceland and Greenland. Others are seen flaming, and vomiting lava amid eternal snows on the edge of the icy continent which surrounds the south pole. The lava comes from them like boiling glass. Steam, too, comes from volcanoes when they are very active, or in what is called a state of eruption, and as it comes it forces up the lava, as the gas of a lemonade bottle forces the fluid out; and with the steam comes also a gas called carbonic acid gas. There are volcanoes at the bottom of the sea, which, at times, send up lava and hot ashes in such quantities as to form islands, around whose shores, as the stuff rises, the sea boils and heaves.

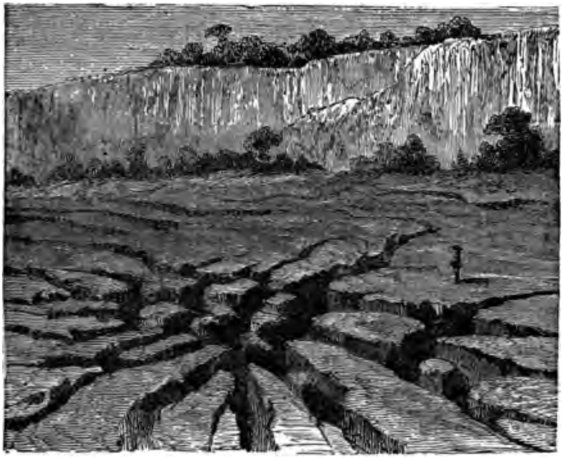

Fig. 3.—Earthquake Fissures.

Then again, the action of the central heat of the earth is felt in earthquakes—shakings of the solid ground which sometimes throw down whole cities, open the ground in wide gaps and close it again, often over hapless men who have fallen into the momentary gulf. We here in Britain are accustomed to think of the solid ground as the surest and firmest of standpoints; but there are lands, such as the West Indies and some parts of South America, where to feel it reeling and rocking like a ship at sea is no uncommon thing. But common as it is, it never loses its terrors.

The immense mountains and chains of mountains which appear to have been forced up through the layers of rocks that were plainly once uppermost, show in another form the effects of the central heat of the earth. Granite, in one or other of its forms, is the foundation of all the layers, and the lowest wherever men can dig far enough. But this, which is the lowest, when the strata are undisturbed, is the highest on many mountains, on the sides of which the stratified rocks lean. These mountains tell of pressure caused by the central heat on the earth's layered surface; they have been formed by the hardening of the lava which burst through when the crust of strata broke under the pressure.

By the action of the earth's central heat, the veins of different kinds of metal which men work must have been formed. We know how heavy the metals for the most part are; but we find them not in the lowest parts of the earth's crust where their weight would have caused them to settle; they are worked where they have been forced into fissures and cracks of the other rocks.

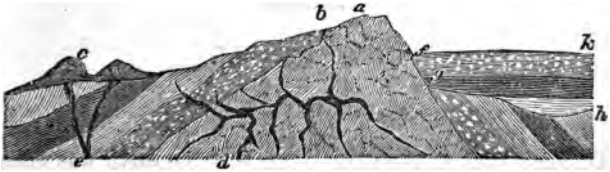

Fig. 4.—Section of Earth's Crust. *a*, *c*, Elevations of igneous rock; *b*, *g*, *h*, stratified rocks leaning on the sides of *a*; *f*, *k*, recently formed strata; *d*, veins of metals.

All these are examples of violent action which the central heat produces. But it also produces tremendous effects in a much greater way. It raises or lowers gradually immense tracts of the continents. The coast of Sweden is rising steadily and so slowly as almost to escape notice, so is the west coast of South America; while the coasts of Holland and the east coast of South America are gradually sinking. The crust of the earth rises at one place and sinks at another under the force of its central heat, as the crust of a pie that is baking swells up and falls in at different parts, from the heat of the oven.

Thus, then, we find that whether men be right or wrong in their supposition regarding the first state of the world; and whether or not the central heat-sources of the earth be the remains of that first boiling fluid, there are certain facts which prove that such a central source of heat exists, and works as a cause of change. Among these are the occurrence of earthquakes, and the existence of thermal springs, volcanoes, and mountains which have burst through all the stratified rocks. The rocks of which such mountains are formed, called granite, greenstone, porphyry, or basalt, according to their differences of appearance or structure, are all made up of matter which has evidently once been melted, and has cooled slowly or quickly. They owe both their structure and their position to the action of fire, and are called, therefore, **igneous** rocks.

CHAPTER II.

THE WATERS.

To come back to the supposition that the earth was once a molten mass, we must now ask, Where were, at that time, the waters which now form the rains, the rivers, and the seas? In those days of the fiery earth-ball there can have been no water upon it, but the two gases—oxygen and hydrogen—of which it is made may have been there; and as the earth gradually cooled they may have at length come together in the form of steam. As the cooling went on, the steam-clouds would condense still more; till at length they began to come down as rain, flowed all over, and formed, at last, the ocean. This ocean, as we know, covers all the lower parts of the hardened crust, and flows round the higher; here it is deep, there shallow; here it is hemmed in between projecting masses of land, there it opens out into wide expanses; here it has a depth of not less than eight miles, there it forms extensive submarine banks or plateaus at no great depth. We know, too, that the land round which it flows is not more than three-fourths of the ocean in area; its greatest heights are probably about equal to the deepest depths of the sea. Supposing that the land were all levelled, it would stand like a tableland some three hundred yards above the level of the sea; but supposing that all the land were thrown down to the bottom of the sea and levelled up, the crust of the earth, in fact, made into a smooth round ball, then the height of the land surface so formed would be about seventy-five yards above the present level of the sea. Were the waters allowed to act alone and unchecked upon the surface of the land—the tides, the waves, the currents, the rains, and the rivers with their ceaseless unrest—then such a level land at such a height would ultimately be formed. As it is, they form these regular layers or beds of rocks which, as we have learnt, are called strata, and through which, as if on purpose to prevent such levelling up or down, the igneous rocks burst forth, and form the magnificent heights of the Alps, the Andes, and the Himalayas. Fire and water, then, work against each other at the surface of the earth, and prevent its being levelled entirely. The fire lifts up the surface, the water grinds it down; and all the layered rocks, no matter how far inland they may be, are but the fiery rocks worn and ground away by water, carried off particle by particle, and dropped at last to the bottom of the sea.

What! all these huge thick masses of limestone rock which stretch for miles and miles over our own and other countries, on which farms are tilled, towns built and roads made—all those vast beds of sandstone—all those breadths and depths of clay—this terra firma, as we often call it, on which men for generations have lived and died, where kingdoms and empires have risen and declined, where ancient forests have grown and withered—has this been once all at the sea bottom, and piled up grain by grain as the waters laid it down? Without a doubt, as any one who will look thinkingly upon the rocks which we call stratified must in the end confess. Look at the rounded pebbles which we often find in the midst of large sandstones from quarries worked far inland, and say, if you can, in what they differ from those now lying in countless thousands on the sea shore. Look at the sandstone rocks themselves, and see their grains all regularly laid; look at the shells which are shut up in them; look with a microscope at the tiny shells which form the substance of the chalk with which the teacher marks on the black board, or the tailor plans his cuts of cloth, and then say if anything can be more likely than that the sandstone and the chalk must have been formed where the creatures that lived and died in the sea could find their graves in the heart of them.

To understand how this has happened we must consider what goes on every day in the sea and on its shores, and around us elsewhere. The hardest stones, enduring as they seem, are exposed to constant tear and wear, both by air and water. The dampness in the air, which forms clouds that hang about the mountains, decomposes or weathers them, and softens them so that they crumble slowly. The dry wind when it comes blows the crumbled particles about as dust. The rain filters into the loose rocks and sinks into their fissures; and when the frost comes the water becomes ice, swells, and cracks off huge masses from the mountain sides. Plants, too, which grow by slowly absorbing small parts of soil on the top of the rocks, and which sink their roots into the rocks, often cause large masses to break off and tumble. The very soil is nothing but worn-down particles of rocks mixed with rotted remains of plants.

The waters which flow down from the hills and form first streams, then large rivers, are active agents in the destruction and wearing of the rocks. These rivers, as they flow onwards, roll down worn-off particles and wear off others by their own force and the grinding of the rolling particles. Sometimes, in a rainy season, they inundate the land, and carry off in their flood all that comes in their way—bridges, railways, grain, houses, and human beings.

The sea works even more fell destruction, as its waves dash up against the rocks. Every wave grinds away its own particles; and sometimes when the tides are high and the wind strong, the mass of waters forces itself over the land and washes it away. In this way were Dollart Bay and the Zuyder Zee formed. The island of Heligoland is being rapidly carried off in pieces by the waves. The small pieces of rocks which rivulets break off, sharp-edged at first, are worn gradually as they roll down the river beds, and become at last smooth rounded stones. The broken rocks—dashed backward and forward by the sea-waves, soon become round, and gradually smaller, till they form small pebbles, and in the end loose sand. Even this sand may be in the course of time ground into mud by the sea, as the sandstone of our pavements is ground by the feet of passengers. For mud is nothing but finely-ground rock mixed with water.

Ice—that is, solid water—takes its part in the wearing down of rocks. The masses of mixed snow and ice, often miles long and many feet thick, which collect in the valleys between lofty snow-covered mountains, are called **glaciers**; and although apparently very still and solid, they are continually and slowly moving down towards the plains. Their enormous weight makes them press and rub against the mountain sides, between which they lie, and their course downwards is marked by the polished faces which they leave upon the rocks, and by long grooves or *striæ*, as they are called. Besides, they carry down with them large masses of stone which have fallen from the mountains on to them. These too become smoothed and striated on their ice-voyage, and are at last deposited on the plains, or in the depths of the sea, where the glaciers, yielding to the sun's heat, melt. Such large stones found lying loose in different parts of the world are called **boulders.**

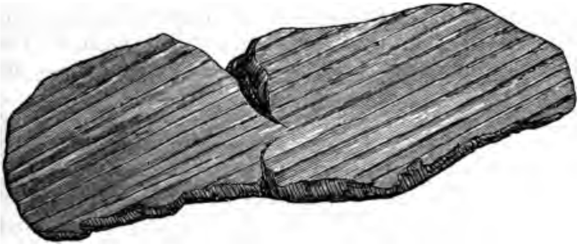

Fig. 5.—FRAGMENT OF STRIATED ROCK.

The light particles of sand and mud formed by the waters are carried off by the waters as they move, and are held in suspension by them so long as they move rapidly. But there comes a time when water, which has been carried rapidly along down slopes, begins to flow over level ground, or is stopped in its course from some other cause. The particles which it has held in suspension begin then to fall to the bottom, and form there what is called a **deposit.** In this way the river Mississippi carries yearly to the sea 900,000 pounds of mud, and the river Ganges forms a deposit beyond its mouth of above six thousand million cubit feet. What rivers carry along and lay down along their plains, and at their mouths, is called an **alluvial** deposit; the deposits formed at the bottom of lakes are called **lacustrine**; those formed in the sea are called **marine** deposits.

The sea is the great former of deposits. It carries off the spoils of pebbles, sand, and mud, which rivers bring to it, as well as those which it wrests from the land for itself, far out towards its central basins. There, becoming calmer than when it was chafed by rocks and sand banks, it suffers them to fall gently down and fill up the wide area at its bottom. With these fragments of the old rocks, as they settle at the bottom, the bones and shells of dead sea animals become mixed up. The shells of animals which live together in beds at the bottom of the sea, like oysters, are covered up by the falling sand and mud, there where they die. The shells of those which in life stuck to the rocks become the sport of the waves for a time, and then, rounded and broken, sink along with the sand, when they get into calm water.

And now what becomes of this mass of pebbles, sand, mud, shells, and bones down there at the bottom? The lower layers have an ever-increasing weight to support, as the sand, mud, and shells heap up higher and higher, sometimes to a thickness of miles. Besides this they have to bear the weight of an ocean miles in depth. They are thus pressed firm and hard; slimy and chalky substances form a cement for them, and then they become stone. We can see this process going on on many shores. The sea mud, which is soft, as it were, to-day, becomes in a few years stone that men can build with.

All this, which is now going on at the bottom of the sea, must have gone on while the rocks which now form the dry land were being heaped up. In the limestone quarries, worked far within the present continents, shells are found, many of which resemble those of animals still living in the sea, broken and lying within the stone, just as the shells of dead ones do among the sand and mud at the present sea bottom. How could this be, unless the sea had once flowed over where these rocks were made? And, let it be noticed, these shells and bones of old sea animals are not found huddled together, among stones heaped in confusion, as if they had all been washed together on to the land by some great inbreak of the ocean. They lie fast buried in the layers of the rocks of the different countries that now exist; and in such a way that they tell us plainly of a long period of repose and heaping up for these rocks and their enclosed remains under the blue waters, before they came to their present position—high, dry, and inland.

How, then, came these stratified rocks, which were once at the bottom of the ocean to be now high, dry, and inland? There are only two ways of answering the question. Either the sea has gone down, or the land has gone up. But there is no good reason to believe that the sea-level changes. Some lands, as we have seen, are rising above it, at the same time that others are sinking below it; and, indeed, there are lands which, it is easy to see, must have been many times alternately above and below the waters. The force of the central heat of the earth will account to us for the rise of the old sea bottoms, which now form the dry land. That force is even now slowly lifting up the shores of Sweden and western South America. It, then, has lifted up the layered rocks. In some places it seems to have done so very gradually, as now it is doing at Sweden; in others it has done its work with great violence and pushing, breaking, shifting, and twisting of the previously regular lying strata. The marks of it all can be plainly seen by whoever will take the pains to see them.

Thus, then, we see the two forces under which the mineral world assumes its form. The force of water, that of rivers as well as that of the sea, which would soon level all, as men do when they make a railway; and the force of fire which lifts up other lands to replace those that are wasted away. In this strife between fire and water, our world has changed its face many a time; and, indeed, is always changing. The world which exists is passing away, and that which is to be is slowly forming under the waters of the ocean.

CHAPTER III.

THE STRATA.

By a careful study of the stratified rocks, and of the remains of animals found in them, a kind of history of the olden world, long before the times even of the most ancient human history, has been made out. It is a history written, as it were, in stone, of which each series of layers forms a volume; a history, indeed, in which pages and whole chapters are often wanting, and which still leaves us quite in the dark as to the beginning of its wondrous story. But what it tells, added to what we guess—as when we guess about the world having been once all in a state of fusion—can be read with a fair kind of connection.

The granite is usually spoken of as the first kind of rock that ever existed, but since we know not the beginning, we cannot be sure of that. We know that it underlies all the others, in one or other of its many forms, and that it overtops them where it has been erupted or forced out. But, taking the history of the world since the stratified rocks began, men make out, or think they can make out, a certain series of changes. First, there was an age or period during which there was no living thing upon the globe. Second, there came a time when soft animals, some with shells, and some without, abounded in the seas which covered the whole world. Third, there came a time when shellfish, coral animals, worms, and fishes were almost the only kinds of living things, and when the few lands which had appeared above the waters began to be covered with simple plants. Fourth, there came a period when continents were often raised above, and sunk below, the sea; and in their times of emergence were overgrown with trees and plants of many kinds, the remains of which exist in our beds of coal. Besides the animals of the previous times, there now lived large amphibious, or land and water animals, as well as some reptiles. Fifth, after that period came a time when reptiles were the lords of creation—reptiles far larger and more numerous than those that now exist. Sixth, the reptiles apparently had died out, and a new time came when quadrupeds formed the chief living animals, but like the reptiles of the age before, they were larger than the quadrupeds we now see. After this came the time in which mankind first appeared upon the earth.

These different periods have received many different names. We may speak of them, respectively, as the age of no life—that of ancient life—the age of reptiles—that of quadrupeds—and that of man. But not uncommonly the series of strata, with the remains shut up in them, and the times at which they were formed, are spoken of as the Primordial, Primary, Secondary, Tertiary, and Quartary periods of rock-formation and life. The Primordial period is divided into what are called the Metamorphic, Laurentian, Cambrian, and Silurian systems of rocks; the Primary, into the Devonian, Carboniferous, and Permian; the Secondary, into the Trias, Jura, and Chalk systems; the Tertiary, into the Eocene, Miocene, and Pliocene; and the Quartary, into the Pleistocene and Recent systems. These are hard names, but they have their convenience, and it is worth while to master their meaning.

The **Metamorphic rocks** are those that rest immediately over the granite. They are evidently stratified, but have been so much changed by the heat from the granite below them, that their sand and mud hardly appear like sand and mud. Because they are thus altered, they have received their name, which means "changed in form."

The **Laurentian rocks** are those just above the last. They were once counted among the metamorphic rocks, but have been lately honoured with a place and a name to themselves, because in them there are found remains of an animal. This animal has received a long name that means the "Canadian dawn animal;" because men think that in it they have found the dawn or beginning of life upon the world.

The **Cambrian rocks** lie next above the Laurentian, and are not so much changed, their limestones and slates being more natural, so to speak. They are called Cambrian, from the poetic and Latin name for Wales, where their mass is very thick. They contain many metals, iron, copper, silver, and gold, and some animal remains. Here and there on the surface of some of the layers may be seen preserved to this day the marks where worms have crawled or bored. A few crabs and shellfish have lived and died on the shores where the worms crawled, and have left their shells, which men find as they split the rocks open.

The Silurian system of rocks gets its name from South Wales, which was once called Siluria. These rocks are formed of a slaty kind of sandstone. Their only preserved plants are sea-weeds. The remains of some animals of the star-fish kind are found among them—some crabs too, and shell-fish and corals. On the layers of slate, as they are separated, men sometimes find the old ripple marks left by the tide as it rolled over the fine sandy beach; these ripples are fixed now in the hardened mud.

The Devonian System is often called the Old Red Sandstone; since red sandstone is the chief among the rocks of which it is formed, and since there is another newer red sandstone. The kind of rock called pudding-stone, from the large pebbles all over it, like raisins in a Christmas pudding, and which looks as if an old sea beach had been hardened all at once as it stood, is a part of this system. Enormous crabs, fishes of curious shape, and even insects, as well as beautiful ferns, have all been buried in these rocks as they were making. They lay quietly enough beside the bones of huge reptiles, till men broke them out of their stone coffins to build houses for the living. Hugh Miller, a mason, was struck by the appearance of these buried animals, and has written an interesting book about them.

The Carboniferous System of rocks is so named, because the period in which they were laid at the bottom of the then existing seas—a very long period indeed, during which the land must have been raised and sunk many times—was a period when the great coal beds of the world were made. The coal is the remains of vegetables that grew when the land was up, were covered by new layers of sand and mud when it was down, and then decayed gradually under pressure, into the form in which we now find them so useful. At this period there must have been large areas above the sea level; immense fresh-water rivers; and a world, on the whole, very rich in plants—tropical plants—growing near to the poles of the earth. Among their leaves fluttered countless numbers of insects; and at their roots, sunk in the muddy soil, huge reptiles and amphibious creatures crawled. The marks of some of their footsteps may yet be seen. The carboniferous is usually divided into two series, the upper and lower coal measures; between them lies a thick layer of limestone. The upper contain most coal—the lower are chiefly sandstones and beds of thin slaty rock. Wells of petroleum, or mineral oil spring out from these rocks, especially from the lower measures. It, too, like coal, is a vegetable substance.

The Permian System is the name now given to one half of the series of layers which used to be called the new red sandstone. It is a series which can be very well observed at Perm, in Russia, and hence its name. The limestone layers among them are called magnesian limestone; and both these and the sandstone layers form excellent building stone. Its plants and animals are much the same as those of the coal strata. From the nature of some of its layers, it is thought that huge glaciers lay among the hills of the land at the time when these layers were forming, and that icebergs floated on the seas above where England now stands, dropping stones on the bottom as they melted.

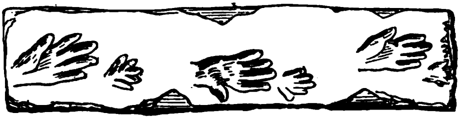

Fig. 6.—FOOTPRINTS ON ROCKS.

The Trias, or triple system, as its name means, is in three divisions: a shelly limestone called by the Germans mussel-lime, a reddish sandstone, and a mottled kind of marly sandstone. The middle layer does not exist in England. This system forms the upper half of the new red sandstone series. It contains beds of rock-salt, and on its sands are many footprints of lizards.

The Jura System, once called the oolitic or eggstone series, is also really three systems of layers : one of grey hard limestone called lias; another of whitish grey limestone, the grains of which are something like the roe, or eggs, of a fish; and a third called the Wealden series, clay and sand which seem to have been laid down in the estuary or frith of a large river. It gets its name from having been first studied in the Weald of Kent. The Bath and Portland building stones belong to this series. Coal, and Whitby jet, of which we make pretty black ornaments, are found among its layers. Some strange reptiles sported in the waters, and even flew in the air, at the time these layers were being laid. One is called, or at least its name means, the "fish-lizard;"* another the "wing-fingered lizard;"† and a third, for want of a better name, men have called "almost a lizard."‡ We have flying quadrupeds now—bats and squirrels; the world had flying reptiles then. England, at that time, must have had nearly a tropical climate.

The Chalk or Cretaceous System consists chiefly of chalk rocks. Some of its layers, however, are of sand, called greensand from its colour. The chalk is mostly formed of the shells of very small animals.

The Tertiary System is that in which the remains of animals and plants begin to show themselves very like the remains which the plants and animals now living will leave for the geologists of some future period to examine. It is commonly divided into three periods: the first in which there lived very few animals of the same kinds as are now upon the earth; the second with rather more; and the third with above half of its animals such as now live. Although many thousand years must have gone by since these periods, they are called recent, in a geological sense. The name of the first, *eocene*, means the far back recent period; that of the second, *miocene*, means more recent; and that of the third, *pliocene*, still more recent. Among the extinct animals of the tertiary rocks, are some the names of which make one feel glad they are extinct—such as the "fierce wild beast,"* and the "great wild beast."† A genial sun must have warmed the lands of the northern hemisphere during the tertiary period. Among its rocks are caves, called bone caves, which appear to have been dens of flesh-feeding animals, and are full of the remains of their prey. Other caves are found, which seem to have been so placed that the waters could wash into them floating dead bodies.

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* Ichthyosaurus. † Pterodactyle. ‡ Plesiosaurus.

The Quartary Period is that in which we live; and its layers are a few deposits of gravel, sand, clay, mud, and peat. It may be called the period of man, and includes those centuries which we are accustomed to speak of as the period of world history, with an almost absurd forgetfulness of the long ages that have gone before. It is sometimes divided into two periods: the diluvial, and the alluvial. While the rocks of the diluvial period were forming, a great change of climate must have occurred, compared with that of the tertiary system. Europe, Central Asia, North America, and all from these to the pole, was one mass of ice, as most of Greenland is now; and in the southern hemisphere, ice extended itself far into regions that are now free. Only a small area near the equator afforded a refuge to the races of animals that, in the period before, had basked in sunshine from the pole far to the southward. From the ends of this icy covering icebergs floated away, carrying huge fragments of rocks which they dropped in their course. Even for long after this severe time came to an end, the glens and hollows of Great Britain were filled with glaciers, which, as they moved, tore and scratched the rocks, laid down thick deposits of clay, with smooth stones and gravel, and rounded the tops of the lower hills.

Before the alluvial period began, the ice withdrew towards the poles, and gradually the present arrangement of our climate came on. Since then the lands have changed their level frequently, and changes as we have seen are going on still—such as those in Sweden and South America.

* Dinotherium. † Megatherium.

How long it is since that epoch of ice no man can tell. Here is one calculation that has been made. The river Niagara has cut a passage between its banks, below the falls, about six miles in length, and continues still to cut its way backward. This must all have been done since the glacial period, as the rocks of the country show. We do not know exactly the rate at which it wears between its banks; it is certainly not so much as one foot a year. But if it were even as much, then the six miles would have required 31,000 years to be carved out. Some think an inch a year is more likely than a foot, and that supposition would lead to a demand of nearly 300,000 years for the work done by the river since the glacial epoch.

Fig. 7.—Glacier of the Alps.

Again, the thickness of the rocks of the quartary period, which must have endured 31,000 years at least, is about 500 feet; that of the tertiary period is six times greater, and if these rocks were formed at a similar rate, this period must therefore have lasted six times longer than the quartary. The thickness of the secondary rocks is

15,000 feet, and it must therefore, by like reasoning, have lasted thirty times longer than the quartary. The thickness of the primary rocks is nearly three times, and that of the primordial rocks about five times, that of the secondary rocks; the times required, therefore, for the heaping of these, is more than the strongest imagination can conceive. And yet we must remember that even before they began to be piled up, the period of the formation of the first igneous rocks had passed away—the period of chaos, if we may so speak—when no life was possible upon the earth. Who shall say how long that lasted? When we read what men of science tell us of the stars and their distances, we are lost in the immensity of space; and when we come to reason on the truths which geology teaches, we are equally lost in regard to time. Truly, men are but creatures of a day.

Fig. 8.—FALLS OF NIAGARA.

CHAPTER IV.

PROPERTIES OF MINERALS.

THE layers of the earth's crust, raised and sunk alternately, sometimes slowly, sometimes suddenly, lie therefore very irregularly one above the other; and do not, as might be supposed, surround the centre, like the coats of an onion. Certain layers are totally wanting at certain places, because the force of the waters which carried the materials to form them has ceased at these places; here a given layer is excessively thick; there it shelves off, becomes thinner, and ceases altogether. In many parts of the world they do not lie horizontally as they must have been laid, when formed at the bottom of a calm sea, but are more or less inclined. In fact, most of the strata of the earth give evidence that they have been displaced since their first formation; some, indeed, many times. Some stand up on end, or are vertical. Others are bent, or folded, as a quire of paper might be folded; in folds, however, which extend over many miles of area. Often, again, they have been broken, and one part of the area which they had covered has been forced away from the other; so that on one side of the break the layers stand inches, or feet, or miles above those on the other side of it. This displacement of layers on each side of a break, or line of fracture, is called a **fault.**

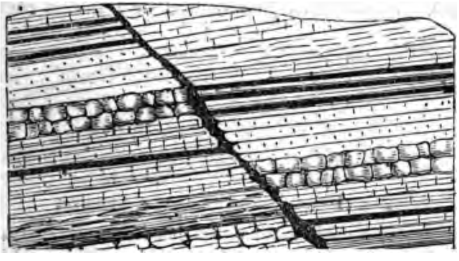


Fig. 9.—FAULT.

It is these disturbances which enable us to judge of the state of the earth's crust miles deep; for when a great depth of layered rocks has been turned up on edge, and the edges brought to the surface, we can see how they have been arranged as they lay, before the force acted which has turned them up. The edges which thus come to the surface are called the **out-crop** of the strata. The angle at which they lean, when they have been tilted up a little, is called the **dip**. When the displaced strata slope away from each other in opposite directions, like the slates on different sides of a house-roof, the part at which they slope off is called an **anticlinal axis**; and this continued along a line of country is called an anticlinal ridge. When strata slope towards each other, and meet in a hollow, this is called a **synclinal** axis, and the hollow a synclinal valley. When ridges have been worn away by water, or any other cause, such wearing away is called **denudation**; and when, in the hollow between the two slopes of an old series of synclinal strata, new rocks have been laid which lie horizontally or at a different slope from those of the older series, the two sets of series are said to be **unconformable.** Sometimes fire-formed or igneous rocks come straight up through a series of layers, and form what is called a **dyke**; at other times they break into branches, filling up cracks, as it were, among the layers, and then they form **veins**; and at others, they force their way between the strata. They are then called intrusive rocks. The groups of layers which are supposed to have been formed in one age or period of the world's history, are usually spoken of as distinct **systems**, or **formations.**

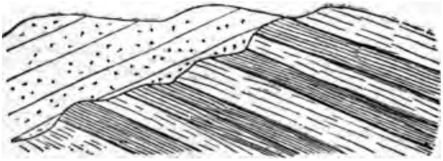


Fig. 10.—Unconformable Strata.

All the materials which make up the crust of the earth, whether hard or soft, in masses or broken into small particles, are spoken of by geologists as **rocks**; and all rocks, whether they be of igneous or aqueous origin, whatever be the formation to which they belong, are composed of masses of mineral substance, either of one kind only, or of many kinds mixed together; that is to say, their mineral masses are by themselves either one of the sixty-five substances called elements, or a chemical combination of two or more of these elements. Chemists consider these sixty-five elements as the pure stuff, so to speak, out of which all the many millions of stuffs in the world have been made. All other things are mixtures of some of them, no one of them can be shown to be made of anything but itself. They combine with each other in certain ways, so that out of two or more of them there is produced a substance different altogether from any of the things combined. Thus, the mineral substance called gypsum is a chemical combination of the gas called oxygen, the solid element sulphur, and of lime and water. But these sixty-five elements do not mix chemically with each other in any quantities in which they may happen to be brought together, so as to produce a new substance different from any of the elements mixed. There are large masses of rock-salt in different parts of the world, and these are all formed of a light kind of metal called sodium, and a yellowish green gas called chlorine. So there is a red earth called cinnabar, which is a mixture of quicksilver and sulphur. But each of these mixtures contains certain definite quantities of the elements mixed—quantities which are constant and fixed in weight or in bulk, 1 portion of one of the elements to exactly $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, 3, and so on, of each of the others. A little more or a little

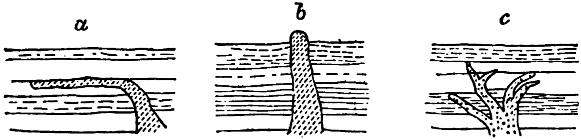


Fig. 11.—Intrusive Igneous Rocks. *a*, Between strata; *b*, dyke; *c*, veins.

less than this 1, 1½, 2, 3, etc., of any of them, would not do as well to form the new substance. If one were to ask a chemist to improve the flavour of salt by putting a little more chlorine into it, he could not do it. And by no means in the world could he give us a cinnabar which would be a little richer in sulphur than any other cinnabar.

Everything in the world, or on it, whether animal, vegetable, or mineral, is made of a greater or smaller number of these elements combined. In what, then, do minerals differ from animals and vegetables? A mineral has not life; plants and animals are living things: minerals, therefore, cannot be said to be born. One piece of salt or iron never produces another piece of salt or iron. Again, minerals grow, but only by the addition on the outside of matter which is already the same as themselves; but plants and animals grow by taking food into their bodies, and changing that food into the matter of their bodies; whatever cannot be so changed, or which is of no further use in their bodies, they throw off as refuse. Besides, minerals and the objects of inanimate nature are always in one or other of the three states called solid, liquid, or gaseous; plants and animals are neither wholly one or other, rather they are a mixture of all three. An oak or a cow seem solid enough, but only about one-fifth of either of them is solid; the rest is either solid, liquid, or gaseous. Inanimate or mineral bodies are of the same structure all through their mass: a stone is the same inside as outside; and by breaking it you have two small stones instead of a single large one. But by cutting a plant or an animal in two, you have not two small animals, or plants, instead of one. It is seen to be made up of quite different parts; and each of these parts is needful for the support of the whole as a living thing. Different parts so arranged as to work together for one purpose are called organs, so that plants and animals are called **organised** beings; while minerals are said to be **inorganic**, or without organs.

In one respect minerals and organised beings are alike; each kind has a form peculiar to it. We know well enough that different kinds of living beings have different forms. A rose has not the same form as a tulip, nor a bear as a lion. So, too, every distinct substance produced by a chemical combination of elements, whether these be combined by art or nature, if the combination form itself slowly and undisturbed, has a special form. When common salt is dissolved in water, and left to become solid again by the water drying off slowly, it is found to be in a mass made up of small particles all of the same shape—that of a cube. When dissolved copperas is left to solidify in the same way, it appears as a mass made up of particles of a very different shape. Minerals so formed, slowly and without any cause of disturbance acting upon them, such as violent heat or violent motion, take a form which is called crystalline; the particles of them are called **crystals**, and have, according to their kind, different and definite shapes, their sides forming an exact number of faces joined to each other at definite angles, and bordered by lines or edges which meet in definite ways. The reason why rocks, and indeed most of the minerals in nature, are not commonly seen as crystals, is because they are rarely formed slowly and in perfect stillness. Most commonly they have become solids amidst much agitation of the matter in which they were dissolved, or have cooled down quickly from a melted state. Even if they have been at first formed in regular crystals, they are commonly weathered and worn in their edges and faces, by the action of water and other causes.

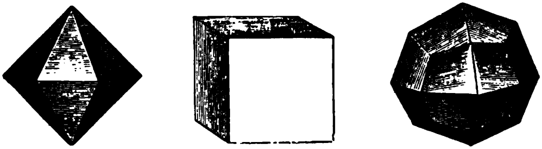


Fig. 12.—Forms of Crystals.

Though minerals have no life in themselves, yet they are the chief, nay, the only support of life in plants and animals. For plants feed on minerals, and animals feed on plants. Some animals feed upon other animals, it is true; but then these last have fed on plants. The relation, indeed, of the three kingdoms of nature—mineral, vegetable, and animal—is this: that plants are the instruments by means of which minerals are made fit to become food for animals.

Minerals, as we have seen, differ from each other in their crystalline forms. They differ also in their mode of cleavage, that is in the directions in which they can be split; for every mineral splits or cleaves more readily in some directions than in others. When a mineral splits readily in only one direction, it is said to have a **laminated** structure. Minerals also differ from each other in weight, taken bulk for bulk; or, as it is called, in specific gravity. Sulphur is twice as heavy as water, flint and slate nearly three times, and clay rather more than twice. Gold is nineteen times heavier than water. Of course a pound or an ounce of the one has the same weight as a pound or an ounce of the other; but if you fill a dish with water and weigh it, then fill the same dish with molten gold and weigh it, the gold which filled the dish, if allowance be made for the weight of the dish, will be found to be nineteen times heavier than the water.

Minerals differ from each other in hardness. Hardness is judged of by the way in which one mineral can scratch another. That which scratches the other most easily is the hardest. There are ten degrees of hardness of minerals: the first, or lowest, is that of chalk; the second, of rock-salt; the third, of lime; the fourth, of fluor spar; the fifth, of apatite, which is a mixture of phosphorus, oxygen, and lime; the sixth, of felspar, one of the minerals mixed up in granite rocks; the seventh, of flint; the eighth, of topaz; the ninth, of corindon or emery; the tenth, and highest degree of hardness, is that of the diamond.

Minerals differ from each other, too, in lustre, or the mode in which they reflect light. There are four kinds of lustre which have received names: the metallic lustre, like that of black lead; the glassy lustre, like that of rock crystal; the resinous or waxy lustre, like that of amber; and the pearly lustre, like that of the inner surface of some shells. Those that have no lustre, like chalk or clay, are said to be dull. The lustres often differ in different surfaces of cleavage of the same mineral. Again, minerals differ in colour. They have a colour of their own, found in all of the same kind when pure; like the yellowness of sulphur, and the colours of the different metals. They have accidental colours also, which arise from a mixture of foreign substances with them; and they have changing colours according to the way in which they are exposed to the light. Such are the varying tints of precious stones.

Minerals differ from each other in the surfaces they show when they are broken by a blow; that is, in their fracture. This is not the same as cleavage. Slates break in layers, flint breaks in rounded shelly lumps, chalk breaks roughly, lead breaks smoothly. They differ, too, in transparency. Metals allow no light to pass through them; that is, they are opaque. Flint lets some light pass through its inner edges, and is said to be translucent at the edges; other minerals are translucent at all their parts; some light passes, but objects cannot be seen through them. Some minerals show objects dimly through them, and are therefore called semi-transparent; others again, such as rock crystal and glass, are perfectly transparent.

Those minerals which are transparent differ wonderfully in their action upon the light which passes through them. Some only bend it a little out of its course; that is, they refract it, and objects seen through them are apparently displaced. Others show the objects seen through them double, because they divide each ray of light that passes through them into two rays. Yet again, by other effects which minerals that are transparent produce upon light, allowing it to pass when they are held in one position, and hindering it when held in another, they have been the means of revealing to mankind much that is strange in regard to the nature of light; while the light, being affected in various ways by the minerals, has afforded also a means of judging of their inner nature.

In the mineral kingdom, nearly all objects are compounds of two or more of the elements. The only minerals that are not compounds, but elements themselves, are diamonds, sulphur, and some of the metals. One chief ingredient in all the compounds is the gas called oxygen. Some compounds of oxygen and other elements form substances which, from their peculiar properties, are called acids. Oxygen, mixed in certain proportions with sulphur, forms the substance called sulphuric acid, or oil of vitriol; mixed with the element called carbon, it forms carbonic acid. When oxygen combines with any substance, and the compound has no acid properties, such a a compound is called an oxide. A piece of pure iron readily combines with the oxygen of damp air and forms rust, so that rust is an oxide of iron. In the same way there is an element called silicon, with which oxygen combines, and forms the substance called *silica* or *quartz*, which is the main ingredient of all sandstone rocks. Again, mixed with an element called calcium, oxygen forms *lime*, which is the main ingredient of all limestone rocks; and mixed with another element called aluminium, oxygen forms the substance called *alumina*, which is the main element in the clays of the world. Quartz, lime, and alumina are thus the rust of silicon, calcium, and aluminium, and form, at the same time, the greater part of the three great classes of rocks or common stones, namely, sandstones, limestones, and clays.

Considering how oxygen enters into all these, and how in combination with another gas called nitrogen it forms the air, and along with another called hydrogen it forms all the waters of the earth and ocean, we may well believe the assertion, that it is one of the most plentiful substances in the world.

The main rocks of the world, then, are oxides. When an acid combines with an oxide, there is formed what is called by chemists a salt. Chalk, in this sense, is a salt formed by the mixture of carbonic acid with lime; and it is easy to see, therefore, that the word salt, as used by chemists in regard to their mixtures, has no reference to the taste of these mixtures.

The word mineral is used to mean only those substances produced by nature, which form part of the crust of the earth. Water and air, therefore, are not commonly considered as minerals; much less are such things as heat and light. Coal, although it is formed of decayed plants, is called a mineral, because it forms part of the crust of the globe.

In considering the kinds of minerals, they may be divided into four classes: first, the *common rocks* or stones; second, the *salts;* third, the minerals that burn, or *combustible minerals,* such as coal or sulphur; and fourth, the *metals.*

CHAPTER V.

ROCKS AND SALTS.

The common rocks or stones are usually divided into, first, *calcareous* minerals, or those which consist chiefly of lime in combination with other substances; second, *silicious* minerals, or those which are mainly quartz or silica combined with other substances; and third, *argillaceous* minerals or clays, which are composed of a large proportion of alumina, along with other minerals. Some of these materials, when very pure and crystallized, are looked upon as precious stones. Thus alumina, pure and crystallized, forms rubies and sapphires.

Calcareous Minerals.—Few substances are more useful than **lime**, or more widely spread over the earth. It is an oxide of the element calcium, a substance which is not got pure in nature, but has to be extracted from its mixtures by the chemist. Even lime is found mostly as a salt, being combined with carbonic acid. This salt is called carbonate of lime by chemists, and exists in many different mineral forms, such as chalk, marble, common limestone, and transparent Iceland spar. It may seem hard at first to believe that all these are but one mineral compound in different forms, yet so it is. A gentleman named Hall succeeded in making common chalk into marble by merely burning it, till it melted, in a closed gun-barrel, and then letting it cool. The shells of oysters and of eggs are also carbonate of lime.

How then is lime got from the carbonate of it? By burning, and thus driving off the carbonic acid gas. Men get the limestone from the quarries, fill a kiln with alternate layers of it and of fuel, and set the mass on fire. The carbonic acid and any water which was in the stone goes off as gas and steam, and what is left is lime, or what we call **quicklime.** When water is poured on quicklime it is taken into the lime, or absorbed. The lime soon becomes very hot, and falls into a dry white powder called **slaked lime.** When a good quantity of water is poured upon this slaked lime a paste is formed; and if still more be poured on, we get at last a solution of lime in water, which is used to whitewash walls, and to purify houses from infection. Slaked lime made into a paste with water, and mixed with sand, forms the **mortar** with which houses are built. Being laid between two stones it cements them by hardening between them. It hardens, because it joins once more with carbonic acid from the air, and becomes again carbonate of lime, which is a solid, and does not dissolve in water. The use of the sand in the mortar is to help on this change, because it divides the paste of the lime, and allows the air to pass readily in among its particles. Were the sand not there, the paste would cake on the outside, and no air, therefore no carbonic acid, could get into it. Besides that, the rough grains of sand yield so many points for the crystals of carbonate of lime to fix upon as they are formed; and thus the surfaces of the stones between which the mortar is laid, the sand grains, and the newly made crystals, soon form a solid mass.

The purest limes, made from carbonates like marble and chalk, set or become hard only in the dry air. Impure limes, such as those that are mixed with clay or mud, set best under water; and thus they are the most useful for building bridges, piers, embankments, and the like. These are called **hydraulic limes**.

The chalk rocks of the world, regarded as minerals, are a mixture of carbonic acid and lime; but when we come to consider the immense areas which they cover, hundreds of square miles in extent, and their thickness, many thousands of feet, it is difficult to believe that which, however, is the actual truth concerning them—that they are formed by multitudes of exceedingly small animals. They are the shells, or remains of shells, of myriads of soft animals; and similar rocks are even now being made at the bottom of the ocean by animals which are forming for themselves shells out of the carbonate of lime, which they get in the sea water. These animals die, sink to the bottom, decay, and leave their shells to pile up into rocks. Even as among the shelly mud, which is now being formed in the known sea bottoms, the remains of animals are being buried; so among the chalk rocks of England, France, Germany, and Russia, shells and the remains of immense reptiles have been buried. These rocks were formed when the countries of which they now form part lay at the bottom of the ocean. They were piled up, grain by grain, in a way which must have taken many thousands of years to rear them, and at a time before the Pyrenees and the Himalayas and the Alps were upheaved by the central fires.

The uses of carbonate of lime are well known. As common limestone it serves for building houses; as chalk, for drawing and marking. As white marble it is used for busts and statuary, and the veined and coloured marbles form some of our finest monuments; it is used also as a medicine and as a manure. The shells of oysters, and the precious pearls which are found in some oysters, are formed of this substance; so, too, is the coral which ornaments the neck of beauty, and that which, sifted from the sea water by the coral animals, grows up into large islands in tropical seas.

There are caves in limestone rocks through the roofs of which water comes dropping, bringing in each drop some of the lime dissolved. As the water falls from the roof, it leaves a small particle of lime behind it on the roof, and as it trickles away after having fallen, it leaves a little, too, on the spot where it fell. The result of this continual dropping through many centuries has been that masses of pure lime hang down from the roofs of such caves like large icicles; and masses of pure lime grow up from the floor to meet them. Those hanging from the roof are called **stalactites**, those rising from the floor **stalagmites**. Sometimes these meet and form splendid pillars in the cave, so that, when lit up by the torches of visitors, it seems like some magnificent temple. Besides the carbonate, there are other combinations of lime, which men prize for use or ornament. Combined with fluoric acid, it makes the lovely crystals of **fluor spar**, and this acid, when got out of the spar, is useful to chemists. It is very biting in its nature, and serves to mark the chemist's glass tubes, as well as for marking out patterns upon glass. Mixed with sulphuric acid, lime forms what is called sulphate of lime, or **gypsum**. When this is heated, a powder is formed that, with water, can be made into a cream, and will harden very quickly. This powder is commonly known as plaster of Paris, and is exceedingly useful as a cement; by means of it plaster casts of statues are made, and moulds are formed from the types of a book. Into such moulds melted metal is poured and allowed to cool, and then we have the exact copy of the book in solid metal. This is called stereotyping a book. Mixed with phosphoric acid, lime forms a mineral called **apatite**. The bones of animals, our own skeletons, and the pearly teeth of the loveliest dames, are chiefly composed of lime mixed with phosphorus and oxygen.

Silicious Minerals.—The basis or chemical foundation of all the varieties of sandstone and sand is quartz or silica—the rust, that is, of the element silicon. This silica takes the most varied forms, and is part of an almost endless variety of minerals. It forms about one-third of all the mountains of the globe, and covers the ground of the trackless deserts of Africa and Arabia. The beautiful transparent substance called **rock-crystal** is pure quartz, so are the rounded pebbles which lie in millions by the sea shore; and so, too, is the precious stone called **Amethyst,** which people once thought could cause its wearer to dream true dreams, and never to have any evil thoughts.

Sand, as we learnt before, is pebbles ground fine. It helps to make soils fertile by keeping the ground porous and open to rain; and it forms the long hills called dunes, by means of which Holland is protected from the sea.

We have learnt its use in the making of mortar; but not the least important of its uses is that of making glass, as it does when it is melted up with potash or soda. Thus it is to sand, in a manner, that we owe the protection and convenience of windows—the many articles of household use and ornament that are made of glass—the mirrors in which we may admire ourselves—the telescopes which open up to us the starry worlds—and the microscopes which tell us of the minute wonders of this one. Sand, which has been cemented by the sea mud and clay, and pressed by the weight of the waves till it has become a hard sandstone rock, serves us to build our houses, and to grind both our cutlery and our corn. It would take long to tell all its uses. There is a light porous kind of sandstone which allows water to pass through it, and is therefore very useful in hot climates. Large dishes are made of it. When one of these is filled with water, the water oozes out in fine drops through the pores. These fine drops quickly evaporate or dry off, and in doing so take heat from the water which is left in the dish. By this means, that water is kept cool and refreshing. Those who have lived in hot climates know how to prize such a service as the sandstone thus renders them.

Flint is one of the forms of quartz or silica. Indeed, the word silica is the Latin name for flint. We all know the smooth, grey, dull appearance of this mineral. It is got chiefly among the chalk formations. It breaks with a shelly fracture; and when two pieces of it are rubbed together in the dark, they give out a faint light and a peculiar smell. Gravel is mostly composed of flints; and alluvial soils are often wholly made up of rolled and ground flint. It is much used, after it has been burnt and pounded, in the making of fine earthenware; and before percussion caps were invented, it was used for gun flints. The reason is, that when it is struck sharply against a piece of steel, it breaks in red-hot particles, which set fire to powder, or to tinder, or any other thing easily kindled. For long ages before lucifer matches were invented, men were indebted to flint for the means of lighting their fires. It forms the finest of millstones, and at the same time the precious stones called **opal** and **jasper.**

In times past, no man can tell how long ago, flint was used by men as iron now is for almost every purpose to which tools could be applied. Knives, axe-heads, spear and arrow-heads, and many other instruments made out of flint by races of pre-historic men—that is, races of which history knows nothing—are found in tertiary strata near places where the forgotten tribes are supposed to have lived.

Quartz, along with two other minerals, one called **felspar,** the other **mica,** forms granite. These three, however, are not chemically combined, but pieces of them are mixed up together mechanically in the rock. Take a piece of granite and examine it, the small pieces of each of them may easily be distinguished. The colourless transparent motes are the quartz; the pinkish yellow or flesh-coloured bits are the felspar; and the small glistening points are the mica. Felspar is a compound of silicon with other elements, and is used for giving a fine polish to porcelain ware. The clay, indeed, of which the finest porcelain is made, called **kaolin,** is chiefly felspar; and thus the same material that forms so much of the oldest hills, forms the pretty modern ornaments of our drawing rooms. Mica is a mixture of silicon, oxygen, and alumina, and is found in other rocks as well as granite. There is a kind of slate called mica slate in which it is plentiful; and it is also found in masses by itself on the shores of the Caspian Sea. It is transparent and splits in thin flakes or plates, so that it is used for glass, where glass would break. The windows of ships of war, for example, are made of it; glass would shatter when the guns are fired. It is made also into transparent doors for stoves, and sides for lanterns, because it stands heat well.

Argillaceous Minerals.—The minerals of which clay, or one of its elements, alumina, forms a part, are called argillaceous, from the Latin word *argilla*, which means clay. Alumina is the rust or oxide of a metal called aluminum. This, although it is so plentiful, being in all clays, has only recently been discovered. When pure it is called **corundum**, and forms two very different minerals. In a crystalline form it makes the precious stones, **ruby** and **sapphire**; and in the coarse state it forms emery; in the one case it is the most beautifully coloured of gems; in the other, a dull dark brown powder.

Emery powder is very hard, and is used for grinding and polishing precious stones, steel instruments, and optical glasses, as well as for cleaning fire-irons and other household implements. For this purpose it is usually spread over gummed paper. It takes its name from the place whence most of it comes, namely, Cape Emery in the island of Naxos. The large blocks are broken with iron mallets, and ground in mills of steel, then mixed with water and stirred. The water is left for half an hour, and then, while the finer portions yet float in it, it is poured off, and what settles from this is called half-hour powder. Fresh water is put to the rest in the first vessel; it is again stirred, and left for fifteen minutes, poured off after that, and what settles now, out of the poured-off water, is fifteen minutes' powder. And so the operation is repeated, till we get the coarsest kind, namely, thirty seconds' powder, which serves to grind hard substances.

The common clays contain only one-fourth of their weight of alumina; about a half is silica; the rest is lime, magnesia, and other substances. They lie in immence beds in many parts of the world. London and Paris stand on such beds. **Clay** assumes many different colours, according to what is mixed with it; and, when very pure, it is whitish, like pipe-clay. We all know its soft greasy feel; how plastic it is when moist, that is, how readily it can be moulded into any shape. It does not allow water to pass through it, and thus it is useful for puddling; that is, for lining the beds of ponds and canals. When dry, it keeps the form which has been given to it in a moist state; and when burnt it becomes red, chiefly because iron is mixed with it. It forms a large part of all good soils. When it is about the half, such a soil is called a loam. Its use in the soil is to keep the moisture from running off, and the earth from being carried away from the roots of the plants.

The sinking of wells depends upon the existence of beds of clay. The rain that falls on the surface of the earth sinks into it, through the sand, gravel, and lighter soils, till it comes to a clay bed. There it stops and collects, and men bore down to it in sinking wells. Natural springs are mostly outflows of water from such reservoirs through a fissure in the surrounding rocks.

Fire-clay is nearly infusible, and is therefore of use in making vessels which can stand an intense heat—vessels, for example, in which metals can be melted and glass made. **Potter's clay** is used for making bricks, roofing tiles, tiles for drains, flower-pots, and coarse pottery. Mixed with sand it is used in making stone bottles, for holding ink, soda-water, blacking and the like. The finer kinds make earthenware and china. It is of great use to sculptors for their first models of statues.

Pipe-clay, white and greasy to the touch, is used to make pipes, and also to clean and whiten the leather belts of soldiers. **Fuller's earth** is a bluish clay, which crumbles in water instead of forming a paste; but it sucks up oil readily, and is used in cleaning woollen cloth from oily dirt.

Slate, or **Clay-slate,** is hardened clay, found in rocky masses in the Highlands of Scotland, in the north and west of England, and abundantly of the very best quality in North Wales. It lies in horizontal beds or strata, and yet it splits, not as the beds lie, but in an up and down direction. It can be split in almost any thickness, and broken off in slabs of any size. Its colour is bluish, or purple; and it is often marked with green spots. We all know its use in schools, and in fishmongers' shops, as well as in the roofing of houses. Billiard tables are made of it, and tables for dairies.

Shale, or Slate-clay, is a soft kind of slate, often found near coal, and usually full of remains of plants and fishes. Fire-bricks are made of it; the shale or schist, called Stourbridge clay, serves best for this purpose. In some shales there is a quantity of the combustible mineral called bitumen, from which oil is made. **Rotten stone**, a substance used for polishing, is a kind of powdery shale. **Red ochre** is clay coloured by iron, and is used in making what are called red chalk pencils. Clay, differently from almost all other substances in nature, contracts when it is heated, because water is then driven out of it. On account of this property it forms an instrument for measuring intense heat, called the pyrometer.

Alum is a mixture of alumina with sulphuric acid. It is made at Whitby, and near Paisley, from a slaty clay which crumbles when it is burnt. The crumbled clay is first dissolved in water, as far as it will dissolve; then the water is boiled off, or allowed to evaporate, and the alum left is got in crystals. It is a transparent sour substance, the crystals of which absorb water readily. When alum is burnt, it leaves a whitish dry mass. It is useful in the making of leather, in papermaking, in dyeing, and in calico printing; bakers use it, too, to make their bread white. Linen steeped in alum will not blaze, so that no one need wear dresses that are liable to take fire. If alum and salt be mixed together in spirits of wine, and the mixture rubbed two or three times over the hands, a piece of red-hot coal can be lifted without burning the fingers. Jugglers are aware of the fact.

Potash is the oxide of a metal called potassium, and is got mostly by the burning of vegetables. Water being poured on the ashes dissolves the mixtures of potash contained in them, and then, being dried off, leaves them. Mixed with an acid called nitric acid, potash forms **saltpetre** or **nitre**, a substance much used in the making of gunpowder, glass, soap, Prussian blue, and many other things.

Soda is the oxide of another metal called sodium, and was formerly got by the burning of sea weeds, the ashes of which form kelp and barilla. Kelp is prepared from sea weeds in the north of Scotland, barilla from those found on the south-east shores of Spain. Soda, however, is now got from sea salt by chemical means.

Common Salt is a mixture of sodium and gas called chlorine. It is therefore chemically called chloride of sodium, just as soda is the oxide of sodium. The ocean is the great storehouse of salt, but there are also many salt lakes and salt springs in the world. Hills of it, hard and compact, exist in Spain and in India. The island of Ormuz, in the Persian Gulf, is a salt rock. There is a great desert in Persia, on the ground of which salt lies like hoar frost. **Rock-salt** is found also in tolerably thick strata. The most famous of all places for rock-salt is Wieliczka, in Poland, where it is found in three distinct layers, the uppermost 200 feet, the lowest 1000 feet below the ground. Houses and long galleries are cut out of the solid salt rock; churches, concert rooms, and stables too. There are lakes in the mines upon which boats sail, and a spring of fresh water rises up through the salt. Rock-salt is got also in Worcester, Cheshire, and Yorkshire.

The uses of salt are well known. It is said to be the only mineral which is used as food by mankind, animals eat it too. It serves to glaze coarse earthenware, and with it fish are cured and meat is preserved.

There is another mineral, however, which travellers assure us is eaten by men, that is, steatite or soapstone—the soft kind of stone, brown and greasy, that we may see tailors use as they mark cloth for cutting. The people of

New Caledonia, and those who dwell on the banks of the Orinoco, eat it. It has other uses, however. The Arabs use it as soap. It absorbs oil and fat. It takes out grease spots from silk and woollen stuffs; and when reduced to a powder and coloured with saffron, it forms a well-known paint called rouge. It is used in the manufacture of fine porcelain, and for polishing mirrors and marble.

The last mineral we shall here mention, is the strange fibrous substance found in rock veins, called **Asbestos.** This name means that which cannot be burnt or destroyed. As a raw material it is most commonly found like chips or blocks of wood; but it is beautifully white, and can be brought to a thready state, when it is as soft and flexible as thistle down. Though so soft, length of time does not seem to wear it; and though it is as ready to catch fire as tow, yet the fiercest heat does not consume it. No known acids affect it, even though it may have been steeped in them for days. With the aid of a little flax, its fibres can be spun and woven into cloth. This cloth when thrown into the fire is not burnt, but comes out white and clean. Asbestos is got in thin seams among serpentine rocks, and consists generally of about one half silica, the rest being magnesia and alumina, with a very small proportion of iron and lime. Veils, purses, and gloves, are knitted of its threads; and paper is made of it. At present it is woven, at Glasgow, into packing for steam engines; in old times it was made into amianthus cloth, in which were wrapped the bodies of the dead about to be burnt. By means of this wrapping the sacred ashes were kept quite distinct from those of the fuel used in the funeral pile.

CHAPTER VI.

COMBUSTIBLE MINERALS.

THE combustible minerals are so called because they can be burnt. The minerals called metals can, indeed, be burnt, but it is only those minerals which are not metals, and can be burnt, that are included under the term combustible minerals. The first of them which we shall mention is **sulphur,** or, as it is sometimes called, brimstone; that is, bren or burnstone. We all know its yellow colour, and the suffocating smell which it gives forth when burning. It is transparent when very pure; and is mostly found in volcanic regions, where the deposits of it are called solfataras. It is plentiful in Iceland, Sicily, and Naples. The water of many springs is mixed with a gas formed of sulphur and hydrogen, and smells like rotten eggs. Sulphur may be got out of such water.

Sulphur melts with very little heat. At first, in the process of melting, it is thin and orange-coloured, then, as the heat continues, it thickens. It burns with a blue flame, and when melted is cast in thick rolls. When it is allowed to boil, and the vapour to condense in a close vessel, it forms the yellow powder which is called flour of sulphur. It is often found combined with lead, copper, zinc, or iron, and the combinations are called the sulphurets of these metals. It is one of the ingredients of gunpower, the others being saltpetre and carbon. It is an ingredient also of the red paint called **vermilion;** and along with oxygen it forms oil of vitriol, or sulphuric acid. Lucifer matches are made by dipping the wooden chip into sulphur first, and then into a mixture of phosphorus. The heat which we excite by rubbing the match fires the phosphorus, the phosphorus fires the sulphur, and the sulphur fires the wood. The fumes of sulphur are used to bleach straw plait, and also to destroy vermin. When sulphur is melted and poured into water, it forms a workable paste, and of this paste moulds are made, by which casts of medals or coins may be taken. Its vapour tarnishes gold and silver. The sulphur which is in the yolk of an egg blackens silver spoons.

Unlike sulphur in almost every other respect, a **diamond** is like it in respect of being combustible. We have learnt already that the diamond is the hardest of minerals; it is also the most valuable. At the same time, it is of much less use than many others. How then is it the most valuable? Because people have a very great desire to possess diamonds, and because they are very scarce. There is, as we say in trade, a great demand and a small supply of them.

Diamonds are nothing but carbon, the same element of which coal chiefly consists. Indeed, their main difference from coal, chemically speaking, is that coal is particles or atoms of carbon arranged in one way, and diamonds are particles of the same element arranged in another way. Diamond is carbon in a crystalline state. Such is the effect which mere arrangement can produce. Could not one manage to produce a rearrangement of the particles of coal, so as to turn pieces of it into diamonds? Many a one has tried and failed. And if they had succeeded, what would have been the consequence? This, that diamonds would then have become as plentiful as coal, and of only the same value. In the meantime, the only known way of increasing their quantity is to find new natural deposits of them. These have long been known in India, and Golconda, in Brazil, and among the Ural Mountains. Recently, a rich deposit has been discovered in South Africa.

Diamonds are little sparkling bits of pure white, or rather colourless, substance. Sometimes, though this is because of their impurity, they are found blue, yellow, green of many shades, and even black. They are wonderfully brilliant, the light playing upon them in every variety of colour. They are got by washing the gravel in which they exist, and are cut into different shapes. The cutting diminishes their size, but greatly increases their beauty. Many wonderful stories are told of how people have found and carried diamonds, and of enormous prices received for them. One belonging to the Emperor of Russia is valued at above four millions of pounds; perhaps the most famous is the Koh-i-noor, or Mountain of Light, which is in the possession of the Queen of England, and valued at somewhat above two million pounds. They are of no great use. Glaziers use small ones for cutting glass; and minute splinters of them are used as drills for boring holes in fine work of different kinds, such as watch-making. Diamond powder is used for polishing gems.

Besides being the hardest of all bodies, diamond is the substance which refracts light most; that is, which allows it to pass through, but bends it out of its course. Being so hard, diamond seems at one time to have been thought incombustible. Sir Isaac Newton, judging from its great refracting powers, reasoned that it must be combustible; for he had noticed that these two qualities always go together in other substances. And he was right, as chemists who lived after him proved, by burning diamonds. They proved, too, that a diamond is only so much pure crystallised carbon, a substance the same as that which forms chalk when mixed with lime and oxygen; the same in fact as that which, mixed with oxygen, we are always breathing from our lungs.

By far the most important of the combustible minerals is **coal**, the twin brother of the diamond. If it were not for coal, a large number of the other minerals would soon be as scarce as diamonds; for it is only by the use of coal as fuel to smelt them, that we can get them. Coal is often called a mineral, although it has never been found in a crystalline state; and although, beyond a doubt, it is of vegetable origin. Coal, in truth, is the mummies of the old world plants. It is the remains of them found where they have decayed, buried under the strata which form the carboniferous or coal-bearing formations. When we burn coals now, we are but compelling them to give back to the world the heat and light which they got from the sun, in those far back times when they were growing plants. How came these coals, or ancient plants, to be where they are, buried under hundreds of feet of rock? A question not easily answered. But men of science for the most part agree in the theory that they grew where they are found. The area of country over which coal is spread is called a coal-field; and the coal lies in *many beds or layers*, called seams, which are separated by layers of other rocks—limestone, shales, and sandstone. Now, every bed of coal has a bed of clay beneath it, called the under-clay. The theorists believe that this under-clay was the soil on which the plants grew that now form coal. But how came the coal, or the plants, to be covered up? By the sinking of the ground on which they grew. The times, called those of the coal measures, must have been times during which the same spot of earth formed dry land—the bottom of the sea—again dry land—and again the bottom of the sea, many times over. When it was dry, trees and other plants grew. When it sank, and it must have done so gently—for trees are often found standing upright as they grew—then the sea which flowed over them deposited shale and sand and mud above them. These, when they were raised up again formed a new soil, on which new plants grew. Then again came a time of sinking; the new plants rotted in their turn, were buried up, and formed, under the pressure of new rocks, another seam of coal. The new rocks rose or were piled up so as to reach the surface, and formed a soil for yet another generation of growing plants. And so on, and so on, for many successive times. There are seventy-five different beds of coal in the South Lancashire coal-field.

The theorists are far from being clear in their explanations of the changes which have occurred in the plants to make them into coal. But that their idea of the formation and origin of coal is in the main correct, is evident from this, that the forms of stems, leaves, and twigs of different plants are all easily seen among the coal. Coal consists of carbon chiefly, and so do plants; and risings and sinkings of the land do occur. How long ago it is since the rising and sinking of the actual coal beds did occur, how long the thick beds of coal-bearing rocks—nearly 7000 feet in Lancashire, with sixty feet of workable coal—took to form, is more than any man can tell.

Everybody in England and Scotland knows the appearance of coal—black, shiny, somewhat hard, not very heavy, and slaty in its mode of fracture. Every one knows, too, how it burns in the open grate; and most know that when it is burnt in close vessels, the inflammable parts pass off as gas, and leave what is called coke behind. There are very many kinds of coal; as many as forty-five are sent from Newcastle to London; indeed, the Londoners seem to have plenty of choice, for as many as seventy different kinds are sold in the city.

The three most important kinds are **bituminous** coal, **cannel** or **parrot** coal, and **anthracite**. The chemist tells us that the chief difference between these is, that the anthracite is the purest carbon, and cannel coal purer than bituminous. The bituminous coal soils the fingers when it is handled, burns readily, and gives off much gas; some varieties of it cake or run together in the fire. Cannel or parrot coal does not soil the fingers, and burns with a bright flame. It takes on a fine polish, like black marble, and is made into inkstands and ornaments of different kinds. Anthracite, stone coal, blind coal, or culm—for it is known by all these names in different places—is of a dull black colour, yields no flaming gas, and, in fact, when burnt yields nothing but carbonic acid gas. It is difficult to kindle, but burns well with great heat where there is a strong draught of air. It is plentiful in the United States; the best quality is got in Wales.

Who does not know the use of coal? It gives us fire, it gives us light, it extracts the metals from their ores, it yields tar, and many other products which are got from the tar—the colours mauve, magenta, and not a few perfumes and so-called fruit essences; it works our machinery for us, drives our locomotives, and does, in fact, anything for us which requires force. Burn a pound of coal, and its heat is the equivalent of a force that would raise a weight of a hundred pounds twenty miles high.

There is a mineral called **lignite** which is usually spoken of as a kind of coal. It, too, is formed of wood which has been changed. It burns with a bright greenish flame, does not cake, and leaves a woody ash. It is far from being so useful for fuel as the true coal. But one kind of it, **jet**, somewhat like cannel coal, is found among beds of marl in many parts of the world. The Prussians call it black amber. It is made into buttons, earrings, bracelets, and almost every kind of personal ornament. In England it is made into articles for mourning wear. The English jet is found near Whitby.

Among the deposits of black amber there are often found pieces of true **amber.** This, too, is a mineral of vegetable origin. It is the resin of trees which grew ages ago, and forms now a hard, light, yellowish, transparent, and easily broken substance. It is found on the shores of the Baltic, and in tracts of ground deposited by the sea, in pieces varying in size from that of a pea to that of a man's head. Pieces of the latter size are not often got. Flies, or their wings and legs, are often got in it; they have stuck to it when it was soft and gummy. None of these insects resemble any living species, which tells that it must have oozed from trees that grew long ago. Its long residence in the earth has hardened and changed it. It is called *electron* in Greek, and from this name of it is derived the word electricity. Amber when rubbed attracts light bodies, and the observation of this may be said to have been the beginning of electrical discoveries. It burns with a pleasant fragrance, and is used to make pipe mouth-pieces and necklaces. It is scarce and dear. One strange thing is, that though it is carefully sought for each year along the Baltic shores, each succeeding year furnishes about the same supply.

Among the minerals, if they can be called so, which are formed by the decay of plants, **peat** ought to be included. This may be said to be half a mineral, half a plant. It is got in marshy lands, some of it harder and much more coaly in its nature than others. It covers a large part of Ireland, and also of France, sometimes in thin layers, sometimes forty feet deep. It is never found in tropical countries; heat, therefore, seems to be against the formation of it. In cold countries the plants which grow in marshes decay among water, and chemical changes take place which change their nature. The peat is either a mass of tangled fibres and roots and stalks, brown and spongy; or it consists of thickly heaped up leaves. In other cases, where the decay and change is most complete, it appears as if it were nothing but a heap of vegetable mould. Often all these kinds are found together in one moss or peat district; the first kind at the top, the last at the bottom.

Peat does not require the long ages for its formation which coal has done. A forest was blown down near Loch Broom, in Scotland, and fifty years afterwards the people were digging peat where it had stood. In the mosses of this country we often find Roman coins, which seem to tell that the peat has been formed since the time of Julius Cæsar. Peat has the property of preserving bodies found in it. It is said that the body of a moss-trooper, one of the old border marauders, and that of his horse, were got in Solway Moss, just as they appeared to have sunk. Heavy objects thrown on to a peat moss gradually sink in it. The peat is elastic, and springs with a person jumping on it. Large masses of floating peat are sometimes seen forming floating islands in marshes.

The chief use of peat is for fuel. Drains are cut in the bog or moss, and then the peat, when dry, is dug out in brick-shaped pieces and stacked. Very wet peat can be taken up soft, shaped in moulds, and then dried. The ashes of some kinds of peat, mixed with water, yield one of the best kinds of hydraulic lime. When it once becomes full of water, or saturated as it is called, of course it will admit no more. The people of Norway make excellent dykes because of this. They build two walls, cram the space between with peat; the water which first gets in swells the peat, and thus the passage of more water is completely stopped.

There are a number of inflammable minerals, some solid and hard, others viscid or treacle-like, and yet others clear like water, which receive the common name of **bitumen.** They burn with a bluish flame, and a thick suffocating smoke. **Naphtha** is one of the thin liquid kinds. It is got in springs or wells at Baku, on the shores of the Caspian Sea, and takes fire so easily that it is dangerous to approach it with a lighted candle. Near the springs of it a highly inflammable gas comes out of the soil, and people stick tubes into the ground through which it comes. A light is then applied to the tubes, and the burning gas is used for cooking, for burning lime, or any other purpose.

Petroleum is a kind of bitumen, not unlike naphtha, but thicker. It oozes out between the layers of rocks in some parts of Italy; and in the island of Trinidad it forms what is called the Pitch Lake, some two miles in circumference. In Burmah, in the United States, and in Canada, there are many petroleum or oil wells.

Asphalte is a still thicker variety of bitumen than petroleum. It is got floating on the waters of the Dead Sea, or in black solid and heavy cakes on its shores. It is found mixed with lime, and therefore less pure, in Switzerland, at the Val de Travers. It is used for the making of artificial pavements.

Among the combustible minerals is reckoned that called **graphite** or **plumbago**, but more commonly **black lead.** It is not lead, but almost pure carbon, like the diamond and coal; only about four parts in every hundred of it are iron. It is a well-known mineral; black lead pencils are made of it, and everybody, therefore, is familiar with its steel-grey colour, its property of marking on paper, the readiness with which it can be cut with a knife, and rubbed out with india-rubber, and how it soils the fingers. It is found in many different parts of the world; the best quality known used to be got among the slate rocks at Borrowdale, but the mine there has been worked out. The mineral is cut by fine saws into thin strips, and then let into a long groove, in a piece of cedar wood, to which another similar piece is afterwards glued; so good pencils are made. Cheap and gritty pencils are made from the powder of the sawings, mixed with gum or coarse glue. Its name, graphite, means that which can write or draw. Besides its use in drawing and writing, it serves for blackening grates and stoves, and keeps them from rusting.

CHAPTER VII.

METALS.

The metals are by far the most important of minerals. So important are they to mankind that poets speak of the stages of human history by them; and tell of a golden age, a silver age, an age of brass, and an iron age. Were there no iron, copper, lead, or tin, the present age would indeed be a poor one, and we who live in it would be no better than savages. Science, art, trade, and manufactures all depend upon these and other metals. They are rarely found in a pure, or as it called, a native state, but are mixed for the most part with other substances. These mixtures are called **ores**. The pure metals, whether found pure or made so, are all elements; boil them or roast them as you will, you get nothing else out of them. The same quantities of the same kinds of metal are, therefore, always of the same value at the same time. It is not so with other minerals. They cannot be purified like metals, and their value varies according to the state in which they are found.

What are metals as distinct from other minerals? *First*, they have a peculiar lustre; *second*, they are all fusible by heat; *third*, they are good conductors of heat and electricity; *fourth*, when polished they reflect heat and light; *fifth*, they are all opaque bodies—that is, they do not transmit light, unless we except gold when it is beaten to a leaf the two hundred and eighty thousandth part of an inch in thickness; *sixth*, they combine with each other in any proportion, forming what are called alloys; and *seventh*, most of them are malleable, laminable, and ductile; which means that they can be beaten thin by a hammer, rolled thin under a rolling-press, or drawn out into wire.

Seven metals were all that the ancients knew, namely, gold, silver, mercury, copper, iron, tin, and lead. Three others, though only recently known, are of great use, namely, platinum, zinc, and aluminum. Above thirty more, the names of which would weary one to read, exist. Some of them are useful, but not very common; others are rather chemical curiosities than useful substances, so let us leave them to the chemists.

There are four metals which do not rust readily, or form oxides, and so tarnish in the air. These are **gold, silver, platinum, aluminum.** The first three are usually called the precious or noble metals, partly because of their great value, partly because of their not tarnishing readily. When they are forcibly combined with oxygen, the slightest cause sets them free, and that often with frightful explosions. The noble metals, like truly noble men, love their freedom. They are strong too, and resist being easily dissolved. There is but one acid, called aqua regia, which can dissolve them. Hence they are often got pure in nature. They are sometimes found among the quartz rocks in largish lumps, named nuggets; oftener they are gathered in small spangles from among the sands of rivers, which have worn down the quartz rocks. The sands are washed with water, which separates the light particles of sand from the heavy gold spangles. Sometimes quartz rock is crushed by machinery, and the gold particles are carefully washed out from the powder.

The precious metals are not easily changed by heat, hence they do not volatilise, or go off in vapour, under a low heat. When there is danger of losing the very fine particles of gold by the washing of the ore or crushed rock, quicksilver or mercury is mixed with it. The mercury unites, or forms what is called an **amalgam,** with every particle of gold; the earthy particles of the ore are then washed away, and the amalgam is heated. The mercury, which is volatile, flies off, and the pure gold is left solid and shining.

The precious metals are remarkable for their great ductility and malleability, gold more so than silver; an ounce of gold can be drawn into a wire 1300 miles in length, and beaten out to the $\frac{1}{280.000}$th of an inch in thickness, or rather thinness, so that it will cover above a hundred square feet.

Gold and silver stand wear better, both as coins and ornaments, when they are mixed with a small quantity of another metal, such as copper. This does not injure their colour. To tell how much of any other metal is mixed with them, we use the term **carat.** Every piece of market gold is considered as divided into twenty-four parts, and the number of carats used in describing it is the proportion of pure gold. Gold coin is twenty-two carats fine, and there are, therefore, two carats of alloy in it; plate is commonly made of gold fourteen carats fine, and ten of alloy.

Gold is the only yellow metal; brass, which is yellow, is an alloy, not a pure metal. The beauty of gold has made it be sought all the world over, and in all times. It is found at present among the Ural Mountains, in California, Australia, British Columbia, and New Zealand. The largest nugget ever found was got in Australia; it weighed about 233 lbs., and was worth above £16,000. In ancient times, before chemists were so wise as they now are, the students of chemical science sought to get gold by turning common metals into it, which is much the same thing as if one were to try to turn green peas into pearls. They believed that there was a substance which could effect the change. The imaginary substance was called the philosopher's stone; and they spent their time and their money in roasting, boiling, and racking in every possible way, every possible material, to find this stone. They prayed and fasted, and muttered charms to help the action of their furnaces. And it was worth their while; for the stone had power, so they thought, to make the old young, as well as to make dross gold. They therefore spoke of it as the elixir of life. It was never found, of course; and even if it had been, so far as the making of gold is concerned, it would have been useless. For when gold becomes as plentiful as stones, it will be worth no more than stones.

Silver is got mostly in the pure or native state. It is found in Saxony, Norway, Hungary, Spain, Peru, and Mexico. Like gold, it is separated from the crushed quartz by means of quicksilver. It is often found with lead. When dissolved in nitric acid it forms **lunar caustic**, or nitrate of silver. People use this in a fluid state for marking ink. It is also of great use in photography.

Platinum is of a light steel-grey colour, and is got like gold, in the form of small flat grains, called pepites, by washing river sands. Large plates of it have been found in the Ural Mountains. It is among the heaviest of metals. Its two more notable qualities are: that it is not easily changed by chemical agents; and that it cannot be melted by the strongest heat of our furnaces. It does not expand much from heat; and hence it is useful for making the standards of measure, such as the standard yard and metre. It is made into crucibles for melting substances which melt only under great heat. But, since it cannot be melted easily, how is it that it can be made into crucibles? Because when fine particles of it are exposed to a great heat, they can be hammered together. Platinum can be reduced by a series of chemical operations to a very fine powder, called spongy platinum. Owing to its not rusting, the mirrors of reflecting telescopes are made of it. Platinum is about five times as dear as silver; and gold is about three times the price of platinum.

Aluminum is not one of the precious metals, but deserves to be ranked with them, because it is a noble metal, that is, it does not rust. It is, as we know, an ingredient of clay; but although it must therefore be very plentiful in nature, it is only in modern times that it has been known as a separate substance, and quite recently that it has been got cheaply enough from its ores to be made an article of common sale. It is of a bluish white colour, malleable and ductile, and is the lightest of metals. Its lightness makes it exceedingly useful in forming levers for very delicate balances, as well as for weights; since a very small weight of it is of considerable bulk, and easily seen. Its most common use is the making of brooches, buttons, and the like.

Mixed with copper it forms an alloy very like gold, which is sold under the name of Abysinnian gold, and in this form it is made into cheap watch chains and pencil-cases. Silver blackens when affected by sulphur, or gas in which there is sulphur; but aluminum does not. The day may come when aluminum can be taken cheaply from the clays in which it is mixed. This will effect a revolution in our manufactures; for in many things it would serve our purposes better than iron—in the making of iron bridges, for example, where its lightness would be a great advantage. Iron bridges have their own enormous weight to support, as well as that of everything which crosses them.

We come now to speak of the common metals, those that rust easily; that combine with oxygen, or with a gas called chlorine, or with the vapour of a substance named iodine, and form what the chemists call oxides, chlorides, and iodides. The most important of these, beyond a doubt, is **iron.** What youthful philosopher, on his way from school, or more probably to school, has not often stopped at the smithy door to watch the bright sparks fly about, before the steady blows of the smith and his apprentice? If he ever set himself to think of the wondrous material that was being thumped between the hammer and the anvil—of its many uses—he was doubtless late at school, or late home, that day. For wondrous and bright as gold and silver are—many their uses—they are not to compare with iron. Men have said that gold rules the world; but what won gold in old times? The sword. What wins it now? Iron machinery, and invention—the result of knowledge. And what spreads knowledge? The steel pen. The poets are right when they call this the age of iron—right in their words, but not in their meaning: they mean that people in this age are harder and more unfeeling than in former ages—their words, rightly taken, express the truth, that it is an age in which great use is made of iron for the benefit of mankind. Pens, and ink too, are made of iron; our best roads are iron railroads; our large ships are of iron; our gas and water pipes; our bridges, anchors, chain cables, bedsteads, stoves, grates, furnaces, ploughs, scythes, spades, hatchets, horse-shoes, knives, chisels, watch-springs, carriage-springs, needles and needle-guns, cannons, swords, sabres, telegraphic wires, locomotives — even the red colouring matter of our blood—all are iron.

This wondrous metal is rarely found in a native state, because it rusts easily. It is mixed in most of the rocks of the world, and gives them, and the streams which flow over them, a reddish tint. Some think that all the pieces of native iron which are found in the world are of meteoric origin—that they have fallen from the skies, and were once masses moving through space like planets, but have been led aside from their proper paths through the attractions of our planet, Earth.

If native iron is not plentiful, iron ores are. One of the most important ores is that called **magnetic iron** ore, or native loadstone. It abounds in Sweden, Norway, Siberia, and in almost all primary formations. There are large mountains entirely formed of it in Norway. It is called magnetic because it attracts iron, as the magnet does; and, in fact, it was the cause of the magnetic force being first discovered; for, they say, a shepherd named Magnes was held fast to the ground by his hobnails and iron staffpike, which were attracted by a rock of this kind, on Mount Ida.

Another important ore is that called **hæmatite.** The name means bloodstone; but it has other colours than that of blood, for there are both black and brown hæmatites. An ore commonly called **brown spar** is a mixture of limestone and iron, and is found plentifully in Austria. It yields the best iron for making steel; and, indeed, native steel is found among it. It is found in England, in Cornwall and Devon, and at Alston Moor.

The **clay ironstone** is the ore from which almost all the iron of Great Britain is made. It is a carbonate of iron, and has many shades of colour. The blackband varieties of it are the best, because the carbon in them helps the process of smelting. It is lucky that, in most cases, ironstone is found along with coal and lime, for these help to smelt it.

Two things must be done in order to get the metal from the ores. *First*, the gases or sulphur they may contain must be driven off; *second*, the stony matter of the ore must be melted and separated from the iron. To effect these, the ores are first broken in pieces and then roasted in heaps by means of coal. The roasted ore is afterwards thrown into a high conical furnace, along with coke and limestone, and exposed to intense heat by a continuous blast of air blowing through the furnace. The limestone under this heat mixes with the earthy matter of the ore, and forms a melted glassy matter called slag, which keeps on the top of the heated mass; while the iron, also melted, and heavy, sinks to the bottom of the furnace. It is run out by means of a hole opened in the lower part of the furnace, and allowed to cool in short thick lumps. In this state it is called pig iron, or cast iron. Its grain is very coarse, and the central parts of the lumps, where they have cooled slowly, shine with crystals. It is impure too, because carbon is mixed with it, partly chemically, partly mechanically. The particles of pure iron are thus kept from being quite close together, and cohering. The effect of this is that cast iron is exceedingly brittle.

To free it from carbon and make it that it will bear hammering, the cast iron is again smelted, and exposed to a flame of fire passing over it, but the coal is not allowed to be near it. As it melts the iron is kept stirred. This process is called puddling. The hot iron is then beaten with heavy hammers, passed between rollers, and at length cut into bars. These bars are placed in piles, heated again, again passed between rollers, till at last it becomes malleable or wrought iron — soft, tough, and capable of being twisted in any way. As cast iron, it was hard and brittle.

To make steel, the malleable iron is embedded in powdered charcoal and heated in brick cases from which the air is shut out. The iron and charcoal combine, forming steel, which is made hard and elastic by being tempered, that is, plunged red hot into cold water. Steel may also be made at once from cast iron by burning off some of the carbon which is in it. If so made it is called cast steel. Thus the making of iron requires immense labour. A halfpenny worth of iron ore, it is said, may be made into thirty-eight thousand pounds worth of watch-springs—the labour alone causing the difference in the worth of the amount of material.

Next to iron in usefulness comes **copper**. The first mines of this metal were worked in Cyprus, from which circumstance it is said to derive its name. We all know its bright reddish yellow colour, as seen in a new penny. It is found pure in the mines of Cornwall; in Norway and Sweden; in the Harz Mountains; in Siberia; on the banks of Lake Superior; and in Australia, at the Burra Burra mines. The most common ore of it is yellow copper, which is found in Derby, Stafford, Cornwall, Anglesea, and in many parts of the world. The richest ore is the red oxide of copper, which is also got in Cornwall. Blue vitriol or copperas is a sulphate of copper, and is got in Anglesea and Cornwall. It dissolves readily in water, and is abundant in the waters of copper mines. It is got out of them by simply throwing in pieces of old iron with which it combines at once. The surphuric acid of the solution leaves the copper to join with the iron, while the copper is thrown down as a solid.

Copper is applied to almost countless purposes. It is poisonous, and therefore all cooking vessels made of it are covered with tin on the inside. But its poisonous nature makes it useful as a covering for the bottoms of ships. The rust of it prevents sea animals from sticking to the vessel and hindering its passage through the water. It is used for roofing; and as it conducts electricity better than any other metal, telegraphic wires are commonly made of it. It is used instead of iron about powder mills, because it does not strike fire like iron. Its power of giving forth sound is great, and hence many musical instruments are made of it. We all know its use as a coin, with which we can buy small quantities of goods.

More things than can well be named are made of alloys of copper. Bronze, for example, is an alloy made of copper and tin; our so-called copper coins are made of bronze. German silver is a compound of copper and zinc, with another metal named nickel.

Mercury, or quicksilver, is a metal which differs from all others in being liquid at the ordinary heat of the atmosphere in our climate. It rolls over the surface of other bodies in bright drops; not sticking to them as water does, but going along like drops of water on a hot iron plate. It freezes when the cold is about 40° below zero, that is, at 72° below the cold which freezes water. It is white, and shines like silver, and, when it is pure, does not tarnish or rust. In countries cold enough to freeze it, the solid mercury can be beaten out like thin paper or tin-foil. It can be squeezed through the pores of a leather bag, and thus formed into very small drops. It is found pure sometimes, in drops, in holes among slate rocks; sometimes it is found as an amalgam with silver, but most commonly it is got, mixed with sulphur, in the red ore called cinnabar. The most famous mines of cinnabar are at Almaden, in Spain, and at Idria, in Austria. The ground about Lisbon is said to contain quicksilver, but not enough to make it worth while to extract it. It is a poisonous substance. The vapours of it bring palsy upon the workmen who manufacture it; and some of its compounds, though useful as medicines in small quantities, are very dangerous when not carefully used. It is mixed with tin to coat the backs of mirrors; in barometer tubes it tells us the weight of the atmosphere; and in the tubes of thermometers it measures the heat of the objects which surround it. It was by means of a rust or oxide of mercury that oxygen gas was first discovered—and this discovery may be said to have been the beginning of the modern science of chemistry.

Tin, the oldest article of trade in the British Islands, is found in the oldest rock formations; and the chief store of it in the world exists at Cornwall. It is not unlike silver, but softer; can be cut with a knife, and crackles peculiarly when it is bent. It can be hammered into very thin sheets, and is then called tin-foil—a substance which we often find wrapt round fancy soaps, cocoa, and sweets, because it keeps out damp. It is sometimes put upon damp walls to preserve the papering. In a pure state it is of very little use. The articles which we usually speak of as tin-pots and jugs are really made of iron, covered over with a thin coating of tin. When mixed with lead, tin forms solder. Although it is so plentiful in England, we import a great deal from Singapore.

Zinc, a very common metal, was unknown to the ancients, because it is not found pure in nature. Its ores are seldom found alone; usually they are got with those of other metals. When the ancients made brass, which is a mixture of zinc with copper, they did not use pure zinc, but one of its ores. The prettiest of these ores is called blende, which name is given to it because it blinds or dazzles. It is a mixture of zinc and sulphur. Much zinc is imported from Germany under the name of spelter. Air and water have but little effect upon it; they form only a thin coat of rust upon its surface, which protects the metal below. It is thus very useful for making rain-water pipes, gutters, tanks, roof-coverings, baths, and cans for holding water. Sheets of it, full of holes, are used for window blinds and meat safes. The galvanic batteries, by means of which the mysterious force of electricity is made to travel along telegraphic wires, are usually made with plates of copper and zinc, which are dipped in some weak acid. Other metals, in pairs, may also be used for the same purpose.

Lead, the dullest and heaviest of metals, which gives out no ring when it is struck, and which, the more it is hammered, becomes the less dense, seems, as some one has said about it, to be dullness turned into a metal. Yet, like some people who appear dull and heavy, it is really useful, and can be dangerous and well as useful. Bullets and small shot are made of it. It has great power of resistance: acids act but slightly upon it, and hence it is of great use in chemical works. Leaden pipes convey water; sheets of lead line water-tanks, and serve for roofing; very thin sheets form the lining of tea-boxes. Mixed with the metal antimony, it forms type metal.

Lead is seldom found native. Its most important ore—that, indeed, from which it is chiefly made—is called galena, or lead glance, and is very like the lead itself, only it is crystalline, and cannot be hammered without breaking. It is found plentifully among the Pennine Chain and the Lead Hills. The pigment called white lead is a carbonate of the metal; that called red lead is an oxide.

The remaining metals are too numerous to describe even shortly. Some of them are very important for their uses; others interesting for their strange properties. **Arsenic**, for example, is at the same time a most dangerous poison and a useful medicine, and yields beautiful green colouring matters. **Magnesium**, when drawn into a fine wire, burns with a light brighter even than the electric light. **Nickel** is the only other metal, besides iron, which becomes magnetic. **Manganese**, in one of its forms, is a black powder which yet is used in the manufacture of glass to make it clear. **Cobalt** is, except platinum, the most difficult of metals to melt, and furnishes beautiful blue and green colours. **Chrome** furnishes brilliant yellows and greens; and **Antimony**, besides its use in making printers' types, is at once a poison and a medicine.

There is a long list of others which might be named. They have been discovered in quite recent times, and this may lead us to believe that there are many others not yet known, the discovery of which will lead to revolutions in our modes of manufacturing articles of daily use and ornament—will, perhaps, change entirely our present ways of thinking about the structure of natural bodies. Continually to find objects new and *hitherto* unknown in nature, and to apply them to furnishing of additional means of comfort and pleasure for mankind—or to the averting of dangers to which mankind is subject—and to the spreading of new views of the wonders and glories of creation, is the law of human progress; and at the same time the most striking evidence of the high nature of the mental powers with which man has been gifted, compared with those of the lower animals.

PART II.

THE VEGETABLE KINGDOM.

CHAPTER I.

GROWTH AND NUTRITION OF PLANTS.

ALL the objects of inanimate or lifeless nature may be considered as made up of a mass of infinitely small particles called atoms; and in a similar way every plant and every animal is formed of a mass of what are called cells, that is, of exceedingly small bags or bladders with a fine skin or membrane, containing in them a liquid, and small solid grains or granules. These cells, as the plant or animal grows, increase in number by dividing: first one cell divides into two and increases in size, then the two become four, the four eight, and so on. While dividing, they also vary in form, and unite themselves in different ways—some being round, others being long and tubular; some marked with dots or rings, others having inside of them fine spiral fibres or threads. Cells are, as it were, the atoms of organic beings. The root, the stem, the leaves of plants, are all formed of heaped up multitudes of vegetable cells, which have, as they were produced, assumed different forms. So the flesh, the bones, the nerves of animals, are also formed of animal cells which have become different as they grew.

The blight upon corn and wheat, which covers the growing grain like a fine dust that sticks to the fingers, is formed of millions of small plants of only a single cell, which grow upon the larger plant, and receive their nourishment from it through the cell-skin. On stones by the side of a well, on damp hedges, and on the face of a rock, we often see a green kind of dust, which, too, is nothing but millions of single-cell plants, all sucking in through their skins nourishment from the things on which they grow. The light grey mould often seen on jellies and fruits dried and preserved, and even on an ink bottle which has not been used for some days, is also a mass of single-celled plants. Though these plants are all formed of single cells, and all present themselves to the naked eye as a fine powder of different colours, yet by means of the microscope men have found out many different kinds of them. So wondrous is the variety which nature can produce from the simplest of sources.

The organs by which a plant grows are the root, the stem, and the leaves. These all exist in the seed, for the seed is, in fact, the young plant. The pippins in the heart of an orange or an apple, beans, peas, nuts, acorns, wheat and oats, are all well-known kinds of seeds. They are young plants; or, more strictly speaking, they are the first cells which, by their increase and changes, make the plant. The fruit, in the midst of which most seeds lie embedded, is the first food which nourishes the plantlet. We human beings are apt to think that the mealy part which surrounds a grain of wheat, or the juicy part which surrounds the pippins of an orange, have been made to grow for our sake; but no, they were placed there for the sake of the seeds. They are, as it were, the mother's milk of the young plant, and nourish it till it is strong enough to find food for itself in the ground and in the air.

After the fruit that contains the seeds falls to the ground, or is gathered, it may lie a long time, giving no signs of life. Seeds, if kept dry, may survive for years, ready to grow or germinate whenever they are planted. In a pea we may easily see the important parts of a seed. Take one fresh, or a dry one, and soak it in warm water; strip off the outer skin, the whole inside forms the young plant, or embryo, as it is called. This inside consists of two thick pieces which are called the seed-leaves or cotyledons, and which are in reality the first leaves of the young plant. Spread open these thick seed-leaves, and you will see that they are joined together by a small tongue-like part, the one end of which is the beginning of the root, and is called the **radicle**; the other, called the **plumule**, is the bud from which the future stem and leaves grow up. The cotyledons, or seed-leaves, are really the first pair of leaves, and are so thick because they contain the first food of the plant. This food may be compared to the yolk of an egg, which serves for the first food of the chicken. It was stored up in summer by the mother plant in the form of a sugary juice or syrup. As the seed was formed in the seed-vessel of the flower, the sugary juice changed into a starchy kind of pulp, which hardened, as the seed ripened, into the firm and mealy cotyledons.

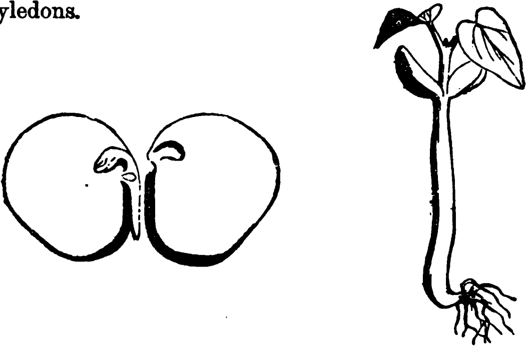


Fig. 13.—Embryo of Pea.

After a pea has been set, and the warmth of spring has begun to act upon it, the cells of which it is composed begin to suck in moisture from the ground through their skins or membranes. The pea swells; the cotyledons burst through their outer covering and throw it off; they then become greenish and thinner; the nourishment contained in them is changed into sugar, is dissolved in the moisture, and absorbed by the cells of the young plant. The radicle then begins to grow downward into the earth; the plumule grows upwards into the air, and as it lengthens it brings the seed-leaves up with it. In a short time the bud between them divides into the second pair of leaves. These are really the first leaves of the foliage; for as the seed-leaves give up their nourishment they wither and fall away. We can see something like this stage of plant growth if we pour water on barley seeds, and let them stand a day or two in a warm room. They swell—the tonguelet grows a little—and the mealy parts of the seed are changed into a sugary stuff, and become, in fact, the malt which the brewer uses in making beer.

What makes the radicle always grow down and the plumule up no man knows; we only know that they do so, and form a complete plant as far as growth is concerned—root, stem, and leaves. All that is henceforth needful is, that the cells at the extremity of the root called **spongioles**, and the cells of the leaves should receive through their walls fluid nourishment from the ground and gaseous nourishment from the air, and should then divide and increase in number and in size. The root as it grows on, downwards, sends off small branches called rootlets; and the stem as it grows on, upwards, produces, and sends off, leaves on stemlets of their own. A pea or a bean does not bring its seed-leaves above the ground; the plumule only rises, bearing at first incomplete scale-like leaves; the radicle sends down two or three rootlets at once, and by their rapid growth the food stored in the seed-leaves is soon all absorbed.

Some seeds have only one seed-leaf or cotyledon. Such are those of all grasses and grain plants, lilies, onions, and many others. Because of this they are classed together under a name which means "having only one seed-leaf." Those which have two, like the bean, the pea, the convolvulus, and the cherry, form another class, the name of which expresses the fact that they have two seed-leaves. Some seeds again, like those of the pine-tree, have more than two seed-leaves, and form a class by themselves. There are plants like sea-weeds and ferns, the seeds of which are merely little round spores, such as one may see on the back of fern leaves. They, too, form a separate class; and thus all plants are arranged into those which have no seed-leaves,* and those which have one,† or two,‡ or many § seed-leaves.

As the plant continues to grow it sends its roots deeper, and increases the number of its rootlets; and it sends its stem up higher. Each joint of the stem has its leaf or pair of leaves, or sometimes a greater number. When each joint grows from the top of the joint before, we have what is called a **simple** stem, as may be seen in lilies, and cocoa-nut trees. But, in most plants, both roots and stems send off branches, or side-shoots. Roots branch at any part of the root, and indeed from any part of a stem that may be on the ground; but branches grow from stems only where the leaves grow. They spring from the corner between the leaf-stalk and the stem. This corner is called the **axil**. The branches begin in form of **buds**. The plumule of a plant is its first bud, and makes the main stem. Those plants which have simple stems have, therefore, no bud but one at the top of the stem, called a **terminal** bud. The buds of plants with branching stems are called **axillary** buds, because they always grow on the axils at the sides of the stem.

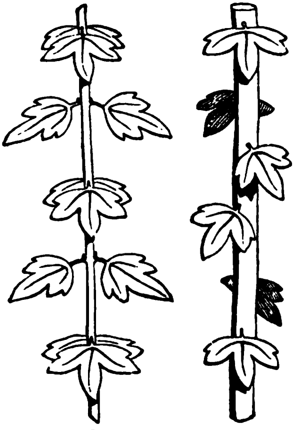


Fig. 14.—OPPOSITE AND ALTERNATE LEAVES.

The place of branches depends upon the place of the leaves. Leaves grow either one on one side of the stem, and then another on the opposite side, higher up—or two leaves grow, one on opposite sides of the stem at the same joint. The first are called **alternate**; the second, **opposite** leaves. In the honeysuckle, lilac, and horse-chestnut, we may see opposite; in the oak, poplar, and convolvulus, alternate leaves. The buds in the axils of these leaves are also opposite or alternate. The regularity of their opposition and alternation is not always kept up, because some of the buds never grow. Many plants have leaves arranged in a spiral order round the stem.

**Acotyledons.* †Monocotyledons. ‡Dicotyledons. §Polycotyledons.

According to the length of life and the nature of their stems, plants are named **herbs, shrubs,** or **trees.** An herb is a plant of a soft stem, which dies altogether, or at least down to the root, within one year of its springing up. A shrub is a plant with a number of hard woody stems, springing altogether from the ground, which lasts for years, and seldom grows to a great height. Trees are plants with thick woody stems or trunks, which live many years.

Some plants live during a part of only one year—some two—some hundreds of years. The first are called **annuals**; the second, **biennials**; the third, **perennials.** Annuals grow up and die in the same season, after they have produced flowers and ripened seeds for next season's growth. Mignonnette and many garden plants are annuals. Biennials do not flower during their first season of life, but do so in the second; and then die after the seeds are ripe. Turnip, carrot, beetroot, cabbage, and cauliflower, are biennial plants. They store up food in their roots, stems, or leaves, during the first season, to live upon while they are flowering in the second. They have usually short stems, and their leaves grow in clusters. When the roots form the storehouse for next years' food, they are large and heavy, like those of the turnip, carrot, and radish. When the leaves and stem form the storehouse, they become thick and fleshy, like those of the cabbage. Sometimes the stalks of the coming flowers form the storehouse, and then they grow as we may see in the cauliflower. Perennials, in our climates, cast their leaves each year as winter comes on. Such are trees, and shrubs, and some herbs. But most herbs die down to the root each year, only a small part of the stem, with buds, being preserved. They too lay up a store of nourishment for the coming year, mostly in the roots, sometimes in parts of the branches, and sometimes in the leaves. In the dahlia, the roots form the storehouse. In the potato plant, underground branches form the storehouse, and men eat these stores. The potato, be it remembered, is not a root; but a swelling at the end of an underground branch from the stem. Such a thickened part of a stem, as a potato, is called a **tuber.** The eyes of the potato are buds, and the small scales behind the eyes are leaflets. Roots, properly so called, never bear buds or leaflets. The real roots of the potato plant are the fibrous parts that run in all directions underground among the potatoes.

When the leaves form the storehouse for the future nourishment of perennial plants, we have what are called **bulbs.** What is usually called the root of a lily is a bulb of crowded swollen leaves—swollen with the food stored up in them, and only a small part of the stem hidden among them. The real roots are at the bottom of the bulb. When the plant grows, the thickened leaves grow up, and then die off in autumn, leaving their thickened lower parts to form bulbs for next year's growth. An onion is a bulb of the same kind as that formed by the lily, only the thick and broad lower parts of the leaves are so formed that the leaves close all round, one within another, forming what we call the coats of the onion. These coats are leaves, therefore, wrapped up as in a bud, not parts of a root.

The wondrous varieties in size which plants present —from the hyssop on the wall to the cedars of Lebanon— and the almost infinite variety in the forms of flowers, are hardly more remarkable than the variations of their roots, stems, and leaves.

Roots.—The main root of a plant is that which strikes out of the seed; but if the stem of a perennial be covered with soil, it makes secondary roots. Such roots are formed, too, when plants grow from slips. A small twig or slip is cut off from a tree or bush, and stuck into the earth. *Its cells* absorb the moisture of the earth as those of a primary root would do; and the slip becomes a plant by sending down rootlets into the ground, and branches up into the air. Some roots strike off from branches growing in the air. The famous banyan tree of India sends down roots from its spreading branches, which grow down and into the ground, and form so many new trunks. One tree may thus have hundreds of trunks, and spread itself so widely that an army may encamp beneath it. The mangrove tree often spreads itself so along the banks of rivers, in tropical climes, and nothing can be more beautiful than the sight from a canoe of groves of wooden pillars, supporting a leafy roof through which the sunlight gleams; while in the water by the banks the genuine roots of the mangrove trail like huge serpents.

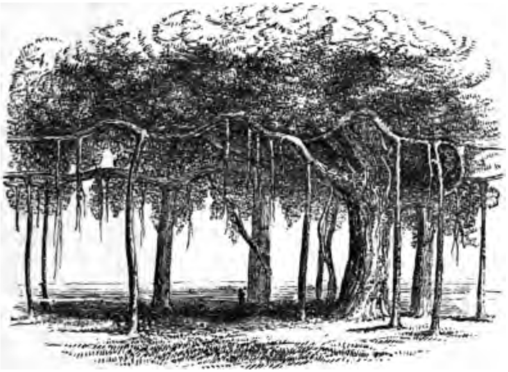


Fig. 15.—Banyan Tree.

Some plants grow only upon the branches of trees. The roots of these are called aerial roots; and the plants receive the name of **epiphytes**. The roots do not sink into the tree upon which they grow, they only lodge on and cling to it; and all their nourishment is drawn from the air. The beautiful tropical plants called orchids are epiphytes. There are seeds, the roots from which strike into the wood of certain trees and draw nourishment from them. These are called **parasites.** Mistletoe is a parasite of the oak. The one-celled plant which causes the rust and smut in corn is a parasite; and the dodder, a kind of convolvulus, is a parasite of clover. There are plants which grow from the ground, and climb round others as they grow, sending out rootlets or **tendrils,** by which they fix themselves to the supporting plant. The ivy fixes itself by means of such tendrils to trees, rocks, and walls. Roots are called **fibrous,** when they are slender and thread-shaped, like that of rib-grass; **fleshy,** when they are thick and stout like a turnip. Those that taper in shape, like the roots of the carrot and radish, are called **tap-roots.**

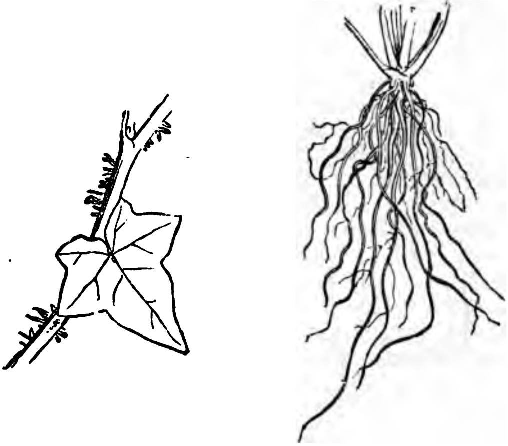


Fig. 16.—Ivy with Tendrils, and Root of Rib-grass.

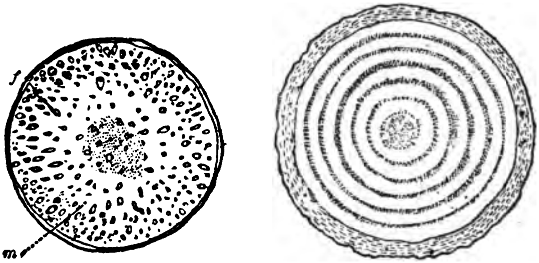
Stems.—The soft stem of an herb is said to be herbaceous; that of a shrub, shrubby; that of a tree growing by a single trunk, arborescent. The stem of grass is called a culm; that of a fern or palm, a stipe. Stems vary in their mode of growth—upright, creeping, climbing, twining, trailing. The parts of the stems at which branches *come off are* called nodes, or knots; and from them the branches come in very different ways. Those of the poplar and cypress rise in nearly the same direction as the upper part of the trunk; those of the oak and cedar spread out nearly at right angles; those of the weeping ash and the elm come off slanting; those of the weeping willow and birch hang down gracefully. Some branches are short, taper to a point, and form **thorns**, such as those of the hawthorn. Prickles like those of the rose, which grow merely from the bark or outer covering of the stem, are not thorns, properly so called. Flower-stalks are a small kind of branches. A branch which rests on the ground, or bends down to it, and strikes root, is called a **stolon**. They are common enough in currant and gooseberry bushes. A **runner** is a thready stolon with no leaves, which gives rise to a new plant, and separates the connection between the new and the old by dying in winter. Strawberries spread by means of runners. A **sucker** is an underground branch, which springs at a distance from the plant that has sent it out, and forms a new plant. Rose and raspberry bushes spread by suckers. An **offset** is a short branch near the ground, taking root where it may touch the ground and producing a new plant. Underground spreading branches are also called **root-stocks**. On the root-stocks tubers are formed.

But it is in the inner structure of their parts that trunks or stems present the most important points of difference. All trunks are made up of two kinds of material—the one of masses of soft and fleshy cells, called cellular tissue; the other of masses of hard and fibrous cells, usually called wood, or woody tissue. In the stems of herbs there is little wood, and a great deal of cellular tissue; in shrubs and trees wood abounds. According to the manner in which the woody matter and cellular tissue is mixed, and to the mode of growth of the trunks or stems, they are divided into three kinds, known by names which mean "inside growing,"* "outside growing,"† and "top growing."‡ The inside growing stems belong to the one-seed-leaved plants; the outside growing to the plants

* Endogenous. † Exogenous. ‡ Acrogenous.

which have two seed-leaves; and the top growing to those whose seeds are spores, or which have no seed-leaves. Cornstalks, a piece of cane, and the stems of palm trees, show the inside mode of growth in stems. The woody fibres run along them lengthwise among the soft matter, so that they can be easily split or torn into stripes. When they are cut across, the ends of the woody fibres appear like so many dots. As such plants grow, the woody parts merely become more numerous among the soft cellular tissue of the inside, and the whole trunk thus becomes thicker. Such trunks or stems have seldom any branches, and do not divide at all, till they come to form leaves and flowers at the top. This is to be seen in the common lily, and also in the beautiful feathery leaves which hang over in an umbrella shape from the top of a cocoa-nut palm. Trees with such trunks grow mostly in the tropics.

The outside growing trees are such as grow commonly in our own woods, and most of our herbs have the same mode of growth. The life of such plants depends upon the activity of the outside layers of cells—those nearest the bark or skin of the stem—in sucking up the nourishment which the roots collect. These cells are, of course, most active when stirred by the warmth of spring and summer. In autumn their walls thicken; their fluid contents, or sap, as it is called, hardens into matter such as the walls are formed of, and the whole of the cells then becomes a mass of woody matter, covered by the bark. Every new year there is formed between the bark and this woody mass a new layer of cells which carry up the nourishment from the roots, while the last formed wood now helps to strengthen the trunk. When, therefore, such a tree is sawn across, its appearance is very different from that of an inside growing stem. Instead of the dotted ends of woody fibres, we see a series of rings of wood which have been formed in successive years. These surround a central part called the pith, *which* is formed of dried-up cells or decayed cellular tissue; and outside of the last of them is the bark. The last year's cellular tissue is called the sap-wood, and is, along with the soft cells on the inside of the bark, the only part of the trunk that is of use in nourishing the plant. The old dried-up cells of the pith and thickened heart-wood are dead; they serve only to support it. Such trees form many branches; and by counting the rings when they are sawn across, one can tell the number of years they have lived.



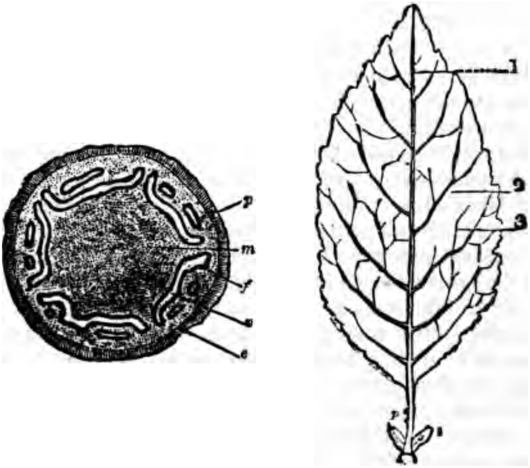
m, Cellular tissue; *f*, woody fibre.

Fig. 17.—SECTION OF AN ENDOGEN AND AN EXOGEN.

The top growing stems are such as those of ferns, and form tall trees in New Zealand and some tropical countries. From their tops hang feathery leaves, and the new matter which causes their growth upward is formed at the roots of the leaf-stalks. The stems are all of one thickness, and are marked all their length up by scars of old leaves. When they are cut across, there is seen within the thick scarry bark irregular marks of woody bundles mixed among a mass of cellular tissue. The centre is often hollow.

Leaves.—The almost endless variety of the shapes of leaves is confusing to a learner; and yet botanists have sought to give every shape a name, because of the ease with which leaves can be described, when each of their little shades of difference can be expressed in one word. Every perfect leaf has the well-known thin green **blade; a stalk,** called the **petiole,** and a pair of leaflets on each side of the stalk, called the **stipules.** A leaf is **simple**

when it is all in one piece, **compound** when in more than one. Leaves, like stems, have their woody parts and their tissue of cells. The woody part forms the fine lacework of veins and ribs, which we may see remaining in a decayed leaf, when all the green pulp or cellular tissue has rotted away. When the veins are parallel along the length of the leaf, as we may see them in grass and in the lily of the valley, the leaf is said to be **nerved;** when they branch off from a thick midrib, and form a network, it is said to be **reticulated.** The shapes of leaves may be best learnt from drawings, with the names of the different shapes attached; and it forms a good amusement, as well as a useful exercise, to look out in the fields for plants which have leaves of the different kinds. The system of exact naming has been carried so far, that not merely the differences of leaves as a whole, but the differences in their points, and in their margins, have all terms to fit them.



p, *m*, Cellular tissue; *f*, *v*, woody bundles; *e*, scarred bark. | 1, Midrib; 2, 3, branching veins; *p*, petioles; *s*, stipules.

Fig. 18.—SECTION OF ACROGEN, AND LEAF OF CHERRY.

CHAPTER II.

FLOWERS AND FRUIT.

THE root, stem, and leaves are the organs by means of which an individual existing plant receives nourishment. But every living plant dies sooner or later. The organs by means of which new plants are produced, and the race of plants is continued in the world, are the flowers and the fruit. We have seen that plants are increased by growth from slips, stolons, offsets, suckers, tubers, and bulbs. They may also be increased, in a manner, by the process of grafting—that is, by sticking a branch of one kind of tree into the stem or branch of another of a similar kind;—a pear branch, for example, into the stem of an apple tree. Or they may be increased by **budding**, which is merely slipping a bud of one plant beneath the bark of another during summer. When spring comes, this bud will begin to grow exactly as if it had been a bud of the branch into which it has been put.

But these are, in reality, merely modes of dividing a plant. It is only by the production of seed that a new plant can be brought into the world. Every species of plants produces seeds, or spores, at one season or other. Seeds are produced by plants that have flowers, such as the cherry tree and the rose; and spores by flowerless plants, such as ferns and mosses.

Arrangement of Flowers.—Flowers grow variously upon their stems. Sometimes only a single flower grows from the leaf axils, or at the end of the stem; sometimes they grow in clusters, with small leaves, called **bracts**, at the part of the stem from which they spring. If either a single flower, or a cluster, have a stalk, or **peduncle**, as it is called, it is said to be stalked or peduncled; if it have none, it is said to be **sessile**. When the flowers grow in a cluster with a common peduncle, the stalk of each separate flower is called its **pedicel**. In some clusters the separate flowers lie on the sides of the main stalk in leaf or bract axils. If the flowers of such a cluster are sessile, the cluster is called a **spike.** The verbena grows in spikes; and willow catkins and fir cones are kinds of spikes. If the flowers be not sessile, but hang from pedicels, like the lily of the valley, the cluster is called a **raceme.** When a raceme is branched it is called a **panicle.** London pride flowers in panicles. If the pedicels of the lowest flowers of the cluster stretch out longer than those above, and so make the cluster flattish, it is called a **corymb.** If the pedicels all spring from the same level on the peduncle, like the ribs of an umbrella, the cluster is called an **umbel.** When the pedicels of an umbel give off smaller pedicels and flowers, they form a compound umbel; such an umbel is formed by the flower-clusters of parsnip, parsley, and

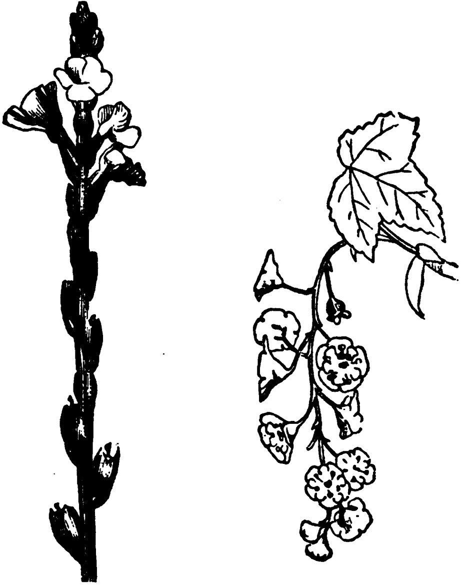


Fig. 19.—Verbena Spike, and Red Currant Raceme.

hemlock. When the body of the flower-cluster is very short, and the flowers are heaped together on it without any pedicels, as is the case of the thistle and the red clover, the daisy and the dandelion, the cluster is called a **head.** A bract, such as surrounds the heads of the dandelion, the daisy, marigold, and similar plants, is called an **involucre.**

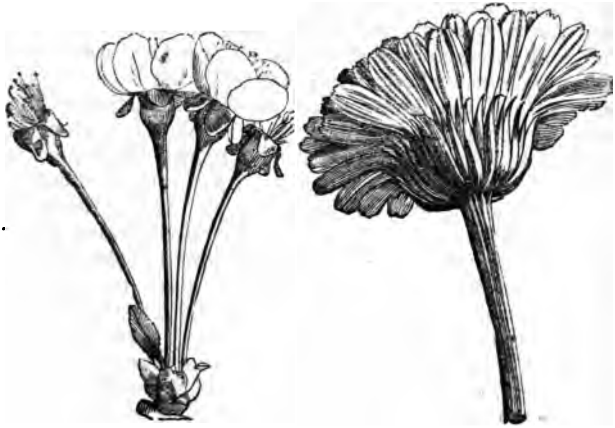
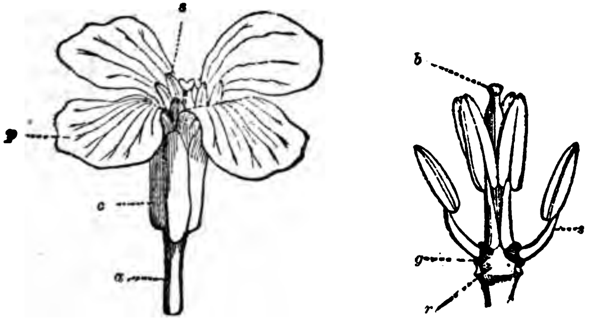


Fig. 20.—Umbel of Cherry, and Marigold.

All these clusters are formed by groups of flowers which spring from leaf axils, and the lower flowers, or the outer ones, of the cluster bloom first; the others bloom later the higher they are up the peduncle, or nearer the centre of the cluster. But if the main-stem end with a flower, and this be surrounded by stemlets which also end with a flower, and give off other stemlets ending in the same way, then clusters may be formed on which the first flowers to grow and decay are not those lowest on the stem or on the outside of the cluster, but the top or central ones of the cluster as a whole, and of each clusterlet. Such clusters are called **cymes;** the elderberry shows us an example of them. A cyme in which the flowers have very short stalks, or none at all, is called a **fascicle.** A bunch of Sweet-William forms a fascicle.

Parts of Flowers.—A complete flower has all its parts arranged from the outside to the centre in four circles, forming whorls, something like four wheels laid one above and within another. The outer or bottom circle is called the **calyx.** It is the cup-like covering of the base of the flower, and is usually green. Each of its separate leaflets is called a **sepal.** The next whorl is called the **corolla,** and forms the coloured showy part of the flower. Its different leaves are called **petals.** These two protect the other two inner whorls, which are really the most important parts of the flower, so far as the production of the seed or young plant is concerned. The third whorl is formed by what are called the **stamens.** They form a circle of thread-like stalks, on the top of each of which is a sort of dusty pouch called an **anther.** This is the main part of the stamen, for in the pouch is contained a fine yellowish brown powder, such as we see well in the anthers of the garden lily. This powder is called pollen, and without it the seed would not be formed. The thread-like stalk of the anther is called the **filament.** Sometimes the filament is wanting; then the anthers lie on some part of the flower, and are said to be sessile. When the flower is ripe the anther pouch bursts, and some of the pollen falls on the end of the **pistil,** which forms the fourth or inner circlet, or rather tube. This pistil or central body has three distinct parts—the uppermost point, upon which the pollen should fall, is called the **stigma;** the middle and thinner portion the **style;** and the lowest part the **ovary.** This ovary is formed by a small bag, or number of bags, called **carpels,** in which lie the future seeds. These are called **ovules,** and only become seeds after the pollen has fallen on the stigma, and grown into the pistil. Till then the ovules are no more capable of becoming plants than so many grains of sand would be.

Whatever the form or colour of flowers may be, however endless the varieties they present, they are all formed on the same plan; and when they are complete they present only these four parts—calyx, corolla, stamens, *and pistil.* There may be few or many sepals or petals, they may be all alike, or one sepal or petal or stamen may differ from another in size or colour; but there is no part of any flower which is not a modification of one or other of them. When these four parts are all present in any one flower, it is called a **perfect** flower. Flowers may be incomplete because they have no petals, like the marsh marigold, they are then called **apetalous**; or they may have neither calyx nor corolla, like those of the willow-tree, and then they are called **naked**;* or, in the same kind of plant some flowers may have pistils, but no stamens; while others have stamens, but no pistils. The blossom with pistil, but without stamens, is called a pistillate or **fertile** flower, because it bears ripe seeds after the anther dust or pollen reaches it from the other flowers of the same kind which have stamens, but no pistil, and are called **sterile** flowers.



a, Flower-stalk; *c*, calyx; *p*, corolla; *s*, stamens and anther; *b*, stigma; *g*, *r*, thalamus, or top of flower-stalk.

Fig. 21.—Wallflower, Outer and Inner Whorls.

If these two sorts of flowers grow on different plants of the same kind, as is the case with the flowers of the willow, the poplar, and hemp, then the flowers are said to be **diœcious**, which means "dwelling in two houses." If they both grow on the same plant, whether it be on the same or different branches, as they do in the oak, the wallnut, the hazel, the birch, and the chestnut, they are said to be **monœcious**, which means "dwelling in one house." Sometimes both of these sorts of imperfect flowers grow along with perfect ones on the same tree. There are flowers, called neutral, which have neither pistils nor stamens. The double flowers reared in gardens, such as double roses and pinks, are of this kind. They produce no seed, and are only good for show.

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* Achlamydeous.

When a flower has the same number of parts of each whorl, or the same number in each row of a whorl, it is called **symmetrical**. Common flax has five sepals, five petals, five stamens, and five styles. In these, and indeed in most flowers, the parts lie in alternate spaces—the petals in the spaces between the sepals; and the stamens between the spaces of the petals. When the different parts do not agree in number, the flower is called **unsymmetrical**. Monkshood has five sepals, and only two petals. The buttercup has five sepals and five petals, but very many stamens and pistils. When the parts of the same sort are not all alike, then the flower is said to be **irregular**. Monkshood is irregular, as well as unsymmetrical, for its five sepals are very differently shaped. The violet has one of its petals larger than the rest, and stretched at the inner end into a kind of hollow spur.

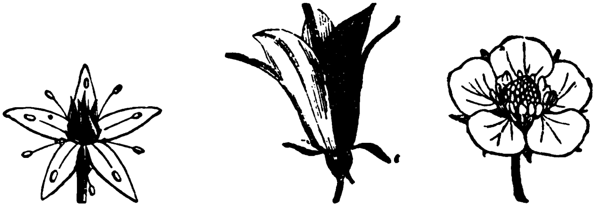

Fig. 22.—Stonecrop, Harebell, and Strawberry

Flowers with separate petals, like stonecrop, are called by a name which means, "many-petalled." * When the petals are all joined into one piece, like those of the harebell, the flower is said to be "one-petalled." † A corolla is **regular**, or alike on all sides as in the strawberry flower; **trumpet-shaped**, as in the honeysuckle; **wheel-shaped**, as in the flower of the potato; and **labiate**, or two-lipped, as we may see in the dead nettle and sage.

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* Polypetalous. † Monopetalous.

Stamens are sometimes joined in bundles. If the filaments are in one bundle, as in the mallow and lupines, the flower is called by a name meaning "one brotherhood;" * if they are in two bundles, as in the pea blossom, where nine stamens are fastened together and one left free, their name means "in two brotherhoods;" † if they are in three bundles, as in the common St. John's wort of our hedges, the name means "in three brotherhoods;" ‡ and if they are in more than three, then they are said to be "in many brotherhoods." §

Pistils are often joined, and form what is called a compound pistil. Most commonly the lowest parts of them, the ovaries only, are joined, and the styles and stigma left free; and then the ovary is said to have as many cells as there are ovaries joined, and each division of the cells, on which the seeds stick, is called a **placenta.** The pistil of St. John's wort is compound.

Lastly, different parts of the flower may be joined together. All the parts stand usually separate, at the head or end of the flower-stalk, as in the buttercup, lily, and flax. Then they are said to be free. But we may have petals and stamens both joined to the calyx, as in the cherry blossom and roses; or we may have the calyx sticking fast to the ovary and helping to thicken its sides, as can be seen in the currant and gooseberry, apple and hawthorn blossoms; or again, we may have the stamens growing on the corolla, and even on the style of the pistil. A pistil is usually, as we have seen, a simple or a compound tube; but sometimes it is open, as if the tube had been unrolled, just as if when we had first rolled up the leaf of a plant and made a tube of it, we might open it out again. The seeds then are exposed, and the flowers are called by a name which means "naked seeded." ‖ The separate scales on the cone of a pine are so many flat open pistillate flowers; and the pollen from the flowers, which bear stamens, can get easily at them to ripen the little seeds which can be seen sticking on the inner face of each of the scales. These united together, in one spike, form the cone. Those flowers in which the pistil is a close bag containing the ovules, are called by a name which means "close seeded." * These two kinds, those with naked and those with covered seeds, form two great divisions of flowering plants.

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* Monadelphous. † Diadelphous. ‡ Triadelphous.
§ Polyadelphous. ‖ Gymnosperms.

When the time of the flower or blossom is over, the calyx and the stamens usually wither, and there remains but the pistil; the ovary of which, being full of seeds, swells, and then we have the fruit. The ovary forms the skin of the seeds, or **pericarp**, as it is called. Simple fruits—that is, those which are the produce of a single flower—are either fleshy, stone, or dry. Among **fleshy** fruits are berries, apples and pears, grapes, oranges, and lemons. In apples, and the like fruits, the calyx has stuck to the pistil, grown thick and fleshy, and the real seed vessel lies in the core or heart of the fruit, such as we see it when we cut an apple or pear across. Among **stone** fruits are plums, cherries, and peaches. The outer part of these is fleshy or pulpy, and the inner hard. The stone is not a part of the seed, but of the fruit. The seed lies within it in a covering of its own.

Dry fruits have no flesh or pulp. Some of them open of themselves when ripe, and throw out the seeds; these are said to be **dehiscent**; that is, "opening." Among these are fruits like those of the peony and columbine, called **follicles**; or like those of peas and beans, called **legumes**; or those of the lily, called **capsules**; or those of cresses, called **siliques**; or those of the shepherd's purse, called **silicles**. Other dry fruits do not open, and therefore the seed is not set free till the coverings have decayed. These are called indehiscent, or "not opening." Among them are the small seed-like fruits of the buttercup, called **achenes**; and the fruits of barley and wheat, called **grains**; and the fruit of the beech and the hazel, called **nuts**; as well as the winged fruits of the ash, the elm, and the plane tree, called **keyfruits**.

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* Angiosperms.

Clusters of fruit, like those of the rasp, bramble, and strawberry, are called **accessory** fruits; because the pulp of them belongs to some other part added to the seed-vessel. A rose hip is such a fruit, because in the tube formed by the calyx lie the real seeds. In the strawberry, the end of the flower-stalk, large and juicy, forms the berry which is covered with small green akenes; seed-vessels, that is, not seeds.

When accessory fruits form masses of fruit from different flowers, they are called **multiple** fruits. A fig, for example, is a hollow pulpy flower stalk, the inside lined with very many small fruits. A pine apple is fruit formed by a cluster of flower leaves and the stalk they grow upon. The cone of a pine or fir is a multiple fruit, each scale being an open pistillate flower.

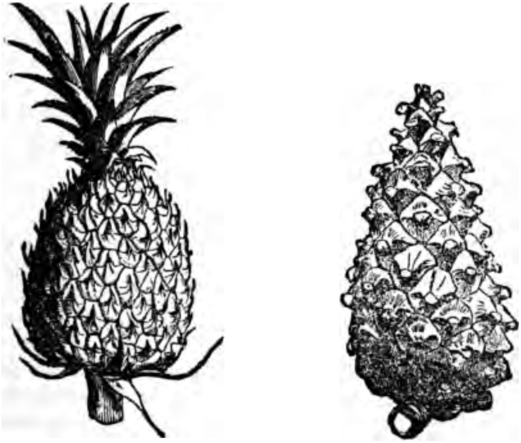
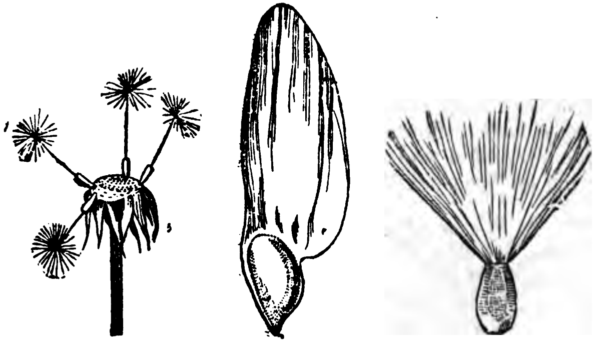


Fig. 23.—PINE APPLE AND FIR CONE.

Seeds.—It is, as we have said, only when the ovule contained in the ovary is affected by the pollen that it becomes a seed, or young plant. In seeds we have the seed-coats and the kernel. A loose kind of outer coat is seen in some seeds, called the **aril.** Mace is such a coat for the nutmeg. The proper coats are usually two, an inner and an outer. The outer coats of some seeds have tufts of hair, or down, such as thistledown; or woolly wrappings such as cotton wool. This outer coat is varied in form; the inner one fits the seed tightly. The kernel is the real seed. This consists of two parts: the young plant itself, and the food stored up for it.



Dandelion. Common Fir. Wild Cotton.

Fig. 24.—DIFFERENT KINDS OF SEEDS.

CHAPTER III.

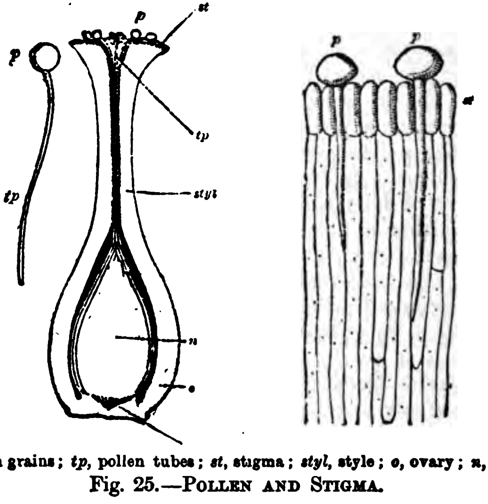
THE FORMATION OF SEEDS.

No ovule becomes a seed till after the pollen has fallen upon the pistil of a plant. The pollen, which seems to the naked eye to be only a fine powder, is in reality, each grain of it, a bag with a double skin, often rough or prickly, and containing a thickish liquid which is full of exceedingly small grains. The pollen bags, when they are put into water, suck it up greedily through their outer skins, and swell up so that they burst, and the grainy liquid falls out. Pure water, or damp, tends, therefore, to destroy the pollen. If, however, the grains of pollen be put into water sweetened with sugar, or into gum, they act differently. The skin of the pollen stretches itself out and forms a long tube or rootlet, in which the grainy liquid of the pollen, called **fovilla**, may be seen moving about. Thus we see that sweetened water causes the grains to grow or develop.

The ovule, which lies inside of the ovary at the foot of a pistil, is also a kind of pulpy mass surrounded by a double skin. It has a small opening at one end, called the micropyle, a name which means "little gate." This opening leads into the heart of the ovule which is hollow, and in which, at the end, the young seed is formed. The important part of the process of formation of seeds within flowers is, that the pollen, as it comes from the anthers, should fall upon the stigma at the end of the pistil; and then, being affected by the sugary juices on the stigma, should grow into it, sending its rootlets down the whole length of the tube of the style into the ovary; and that there it should grow into the micropyle of the ovule. The stigma of a plant covered with pollen, and the rootlets of the pollen growing down within it, present on a very small scale the appearance of a pin-cushion into which a number of long pins have been thrust up to the head. Why all this is needful to make the ovule of a flower into a living seed, no man knows; all we know is that it is so; and even that knowledge has only been obtained in very recent times, after most careful watching with microscopes, by men devoted to the study of nature.

Since it is so necessary for the food of animals that plants should grow, it becomes a most important matter that their stamens and pistils should be well secured, and that the pollen which ripens the ovules should always be able to reach the pistil, or rather the ovules shut up in the ovary at the base of the pistil. In many ways we may see the parts of plants wonderfully adapted to ensure these objects.

A corolla is not merely for show, it serves for protection. Some plants close it up over the stamens and pistil when the dews of night come on; others bend themselves so that the open cup of the corolla, which looks up during the day, looks down at night. Labiate flowers form a dome of their upper petal, and the monkshood forms a helmet of its upper sepal, which are both effectual screens for pistil and stamen. Some kinds of violets, sorrel, and balsam, and some leguminous plants have, besides their more showy flowers, smaller ones, with the corolla firmly shut over both stamens and pistil. These small flowers are the most productive. In them the pollen grains do not fall from the anthers at all, but send down their fine thread-like tubes to the foot of the filament, and thence up to the stigma. The threads hang like a skein of pearly silk between the anthers and the stigma.



p, Pollen grains; *tp*, pollen tubes; *st*, stigma; *styl*, style; *o*, ovary; *n*, ovule.

Fig. 25.—POLLEN AND STIGMA.

Where, as in most plants, such as a cherry-blossom, the stamens and pistil are quite close to each other, and *of about* the same length, it is easy enough for the pollen dust to light upon the stigma as the anthers burst. But there are plants in which this is not so easy, because the style of the pistil is much longer than the filaments of the stamens, and its stigma, therefore, high above the anthers. In such plants, when the time comes that the anthers are ready to burst and scatter their pollen, the pistil bends itself till the stigma is close to the anthers, waits so bent till they burst, and when a grain of pollen is cast upon the stigma, rises up again, as if it knew that the life of the ovules was secured. The fuschia, which has also the style longer than the filaments, by the graceful mode in which it hangs downwards, secures that the pollen must pass the stigma as it falls.

A strange story is told of the way in which the falling of the pollen on the stigma is ensured for a plant of the birthwort kind. The corolla of this flower is in appearance something like a closed tulip, but it is formed of only one petal, not of six, like the tulip. It is thus completely closed, with the exception of a small hole at the upper end, which bends round in the manner of a horn. This hole is the only inlet to the heart of the flower. Within are both stamens and pistil, but the anthers are not upon stamens which reach to the stigma, they grow sessile on the lower part of the strong and thick pistil. That the pollen should reach the stigma in a flower so formed is almost impossible, but an insect brings this about. It is attracted by the scent of the flower, and enters. Long hairs, which are placed on the sides at the entrance, and lean inwards like the wires of a mousetrap, admit it easily. It feasts as it pleases on the juices of the flower, but as it comes away these hairs rise up, enlace it, and keep it prisoner. Caught so, it flutters about, in anguish, doubtless, and by its troubled movements scatters showers of pollen over the stigma. It would be pleasant could one tell that after this was done the poor fly made its escape; but no, its prison becomes its grave—it dies that future generations of birthwort may live.

In the greater number of flowers, however, it would seem to be necessary for the growth of strong plants, that their seed should be ripened, not by the pollen of the same plant, but by that of some other of the same kind. And, indeed, in many plants the structure or mode of growth is such that the pollen from the anther cannot fall upon the stigma of the same flower. Sometimes the anthers are ripe before the stigma, or the reverse; often the anthers are so placed that even if the two ripen together the pollen falls away from the stigma. And in all cases where one plant bears only flowers with pistils, and another only flowers with stamens, that is, in all diœcious plants, the pollen of one plant must ripen the seeds of another.

But how can pollen of one flower be made to fall upon the stigma of another? Insects, and the winds, and the waters, are the chief agents in this work. The wind that wafts our ships, and brings us warmth and rain, brings life to the as yet lifeless ovules of plants. It shakes the flowers, causes the tender anthers to burst, and scatters the pollen far and wide. Much of it is lost, of course; but nature is abundant in her productions, even while little is required to effect her processes; and though only a few pollen grains, as they are lightly blown about, reach the pistils of the waiting flowers, these few of each kind that do reach their destination suffice to cover the earth with the rich vegetable growth which we see around us. It is said that a date palm tree, with only pistillated flowers, which grew at Otranto, in Italy, remained for a number of years producing ovules in plenty, but never able to produce seeds that would grow. During these years there grew a tree of the same kind at Brindisi, about 40 miles distant from Otranto. This tree produced flowers with anthers.

So long as the tree at Brindisi was young and overtopped by the other trees of the neighbourhood, the one at Otranto produced no seeds that would grow. But when the first grew higher than the neighbouring trees, the tree at Otranto bore seeds; for the pollen from that at Brindisi, now that its flowers grew high enough for *the wind to* catch it, was carried from the one place to the other. In the Botanic Gardens at Berlin there is a plant bearing pistils only; and no anther-bearing plants of the same kind grow nearer than America. Yet the plant bears seeds capable of growing, because every year the wind brings pollen across the Atlantic. At least such is the statement made by the scientific men of Berlin; perhaps it may yet be shown that the solitary plant in Berlin bears some flowers with anthers as well as those with pistils, although they have hitherto escaped the eagle eyes of the botanists of Germany.

The waters of the ocean and of rivers take also a part in the work of carrying pollen to flowers with pistils only. There is a famous plant which grows at the bottom of the Rhone, and other rivers, called the vallisneria. It is a diœcious plant, which means, as we have learnt, that pistils and stamens never grow on the flowers of the same plant. The flowers with pistils grow on a long pedicel as fine as a thread; those with anthers grow on a short stalk, and are covered by a closed leaf. The calyx also is closed, and both closed leaf and calyx contain air. When the pistillated flowers have grown up to the surface of the waters they float there, held by their long pedicels. About the same time the curved leaves of the anthered flowers lying at the bottom of the river open, and the flowers are detached from their short stalks. They immediately rise in crowds to the surface, buoyed like little balloons. At the surface these flowers open and scatter their pollen. This floats upon the water, protected by a gummy kind of covering. Some of it comes in contact with the pistils of the other flowers. These flowers then slowly roll up their long stalk like a cork-screw and sink to the bottom, where in time the seed is formed.

Mankind also helps to distribute the pollen of plants. Gardeners sometimes carry it from the anthers of one kind to the pistils of another of nearly the same kind; and then a seed is ripened which produces flowers that have the beauties of the anther-bearing flowers mixed with those of the pistil-bearers. Such flowers are afterwards spread by cuttings. The Arabs take care that the dates, upon which they depend for food, grow well. They take a number of anther-bearing flowers from the trees on which they grow; with these they climb the trees on which those with pistils alone grow; they cut into the bunches of these last with a knife, and stick some of the anther-bearing flowers among them. Without this care it is found that the dates rarely grow well, or are of bad quality.

Some flowers remain in bloom a long time; others wither almost immediately after they have opened. When the pollen has once reached the pistil, and the means of ripening the seed have thus been attained, the work of the flower is done. It may wither away any time, for the life of a new race of plants has been secured. The rhododendrons of our gardens bear many flowers; but none of them endures in bloom more than a day or two. If, however, when they have just opened, the stamens and pistils be cut away, then the flower remains open many days. One is apt to think that it is waiting in expectation of what now can never happen—the coming of the pollen to the pistil. All the double flowers of our gardens remain long in bloom, because, as we have seen, they are neutral flowers. They can never ripen seeds, for their stamens and pistils have become changed into the petals which form the double corolla. All flowers which bloom for a long time, do so because a long time is required for the anthers or the pistils to ripen; or for the pollen to find its way from the one to the other.

CHAPTER IV.

THE LIFE AND DECAY OF PLANTS.

THE life of plants, like that of animals, is a mystery. How it begins and why it ends no man can say. We can do no more in a right study of them than notice what the parts of plants are, and how these vary in shape and *position*; and next observe the order in which the chief changes in them occur. So far we have learnt something about their organs of nutrition—namely, the roots, stems, and leaves; and also something about their organs of reproduction—that is, the flowers, especially their stamens and pistils. We have learnt how the pollen must enter the pistil before the seeds can ripen and grow; let us now see how the different parts of the growing plant work together to keep it in life.

Like animals, plants are born, grow, fade, and die. A plant may be said to be born when the heat and moisture of the ground have begun to make the seed swell, and the seed-leaves give up their sugary substances to the young rootlets and plumule. Before heat and moisture act upon the seed it can hardly be called a living thing. It lasts through winter without any change; indeed, it would not change during many winters if kept where heat and moisture cannot affect it. Even in spring, after it has been sown, if the ground be warm but not moist, seed will not grow. The life of a plant begins only when heat and moisture together bring about those changes that cause the radicle and plumule to spring forth from the seed-covering.

As soon as the young roots are strong enough to draw their nourishment from the ground, and the leaves strong enough to draw theirs from the air, the seed-leaves die. The roots absorb only moisture and whatever may have been dissolved in the moisture. No solid substances can enter as food into a plant; for, as we have already learnt, all plants are formed of cells, within the walls of which are certain liquid and granular matters. These cell walls are made of a substance called **cellulose**, something like starch, and their contents are of various kinds—albuminous matter like the white of an egg, or woody matter, or starch, sugar, oil, fat, or colouring matters of different sorts. With the naked eye the cells of an orange may easily be seen. Cells are of all shapes, and may be lengthened out and joined together, and their touching sides broken away, and thus they may form tubes and vessels of different kinds. The contents of such tubes and vessels also varies greatly—some are full of hard woody matter; others have fine juices in them, or spiral threads winding along them, such as those which can be seen on breaking gently the leaf-stalk of a strawberry.

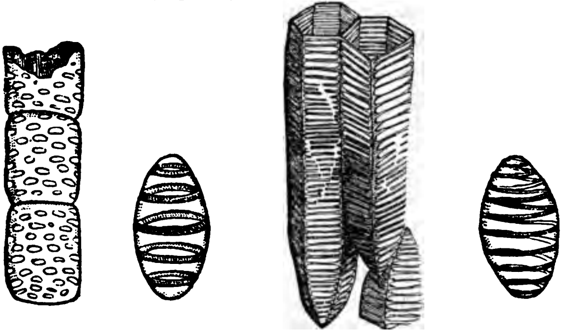


Fig. 26.—Different Kinds of Cells.

But the cells and vessels, be they longer or shorter, are closed on all sides, and have no direct passage from one to another; even the ends of the finest root-fibres, the spongioles, are closed cells. Some people think that the ends of the roots are so many little open mouths which lead into tubes that carry the sap, as food, into the body of a plant, as the blood is carried through the body of an animal. But plants have no mouths, and no blood-vessels, or sap-vessels. From root to top they are cells—-cells joined, cells twisted, cells lengthened, cells hardened, cells varied in many ways, but always closed. Clearly, then, they can receive no solid food. What they do receive is either solid or gaseous. But how does it get into them? Through the skins of the cells. If to one end of a fine glass tube you fix a bladder filled with water, in which a good quantity of sugar has been dissolved, then slip it into a basin of pure water, and let it stand a while, this is what will happen: the pure water from the basin will find its way through the skin into the bladder, and will mix with the sweetened water, diluting it, and stretching the bladder. It will rise up in the glass, too, and trickle out at the other end. A smaller quantity of the sweetened water will ooze out of the bladder and mix with the water in the basin. This will happen although there are no holes or pores which can be seen in the bladder. Any two liquids of different densities, such as water and alcohol, will similarly exchange places and mix together, in similar circumstances. Such passage into each other of liquids, separated by skin or membrane, is called **Osmose,*** and precisely such a passage takes place in the root-cells of plants. The thin solution of earthy matters which is contained in the moisture of the ground passes through the walls of the spongioles, mingling with the thicker liquid they contain. In the same way, by osmose, it passes onward out of the spongioles into other cells, and from one to another, till it reaches the extreme cells at the ends of the topmost leaves.

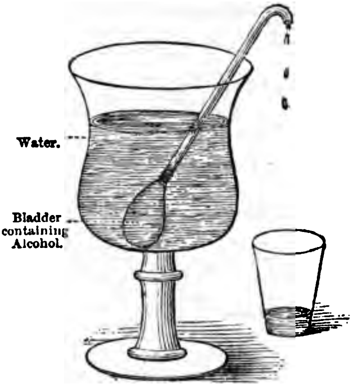


Fig. 27.—Osmose.

This strangely travelling liquid is called the **sap.** It rises in great quantity in plants during the spring, when the increasing light and warmth of the year renews their vigour; and ceases to rise when the first chills of winter come on. The different cells through which it passes act differently upon it, or it on them. In some it becomes thin, in others milky, gummy, and thick; and perpetual exchange goes on between the contents of the cells with thinner and those with thicker fluids. The sap is helped up also from the roots by the drying off which takes place at the leaves as they spread themselves out in the sunshine.

The nourishment of plants consists chiefly of three things—water, carbonic acid gas, and ammonia. Water is formed, as we learnt before, of two gases, oxygen and hydrogen. Ammonia is also formed of two gases, hydrogen and nitrogen. Carbonic acid gas is formed from a mixture of the solid substance, carbon, and oxygen gas. Besides these there is in the food of plants a very small quantity of some other substances, such as phosphorous, iron, and sulphur. They are all mineral, inorganic substances; the plant, in a way unknown, changes them into its living organised substance.

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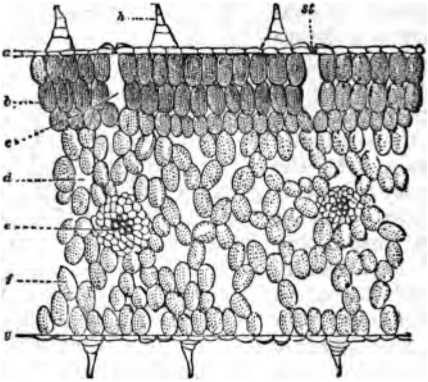
* The going in of the one liquid into the cell is **endosmose**; the going out of the other **exosmose.**



st and e, Stomata; a, g, upper and lower skin of the leaf; d, air holes; b, f, cells; e, vessels; h, hairs.

Fig. 28.—Section of Melon Leaf.

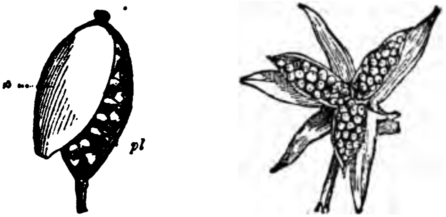
But plants receive their food by the leaves as well as by the roots. These transpire or give out water, but they also drink in, or absorb, substances useful for the plant—water when it is needful, and gaseous food. When the sun shines upon them they absorb some of the carbonic acid gas which is always contained in the air. The skin of the leaf is full of small holes called **stomata.** These are especially numerous on the lower side of the leaf, and open and close as the water in the air, and the light, act upon them. Through these stomata the carbonic acid gas is absorbed under the influence of the sun's light. By means of the green colouring matter of the leaves, or in some other way unknown, plants have the power of separating the carbon from the gas. They let the oxygen gas go back free into the air and retain the carbon, which indeed forms rather more than half the substance of most plants. During the day when the sun shines they are continually absorbing, or breathing in, as we may say, carbonic acid, and breathing out oxygen gas. At night they do neither. There is no growth of plants in the dark, except during the little time that the seedling and rootlet are fed by the food stored up in the seedleaves. Plants are truly children of the sun.

Now animals, both day and night, are doing exactly the reverse of what plants do when the sun shines. They breathe oxygen in and carbonic acid gas out. What the one breathes out as useless, the other breathes in as a necessity of life. Thus there is a wondrous fitting of animals and plants to exist together on the earth. Plants fit the air for animals; animals fit it for plants.

The sap which is sucked in through the skin of the root-cells is called **crude** sap. It is carried from cell to cell up through the stem, by osmose, not by any kind of tubes. To rise an inch in the stem of a plant, the crude sap must pass through many a hundred cells. At last it reaches the leaves, is spread throughout their surface, and the water is dried out from it. The other matters brought in the sap are changed here in the leaves, by the action of sunlight, into vegetable matter. The whole plant, in fact, is so much changed carbon, hydrogen, oxygen, and nitrogen—these things having all been received into its substance as carbonic acid, ammonia, and water; or, perhaps, it would be more strictly correct to say, that the plant is so much changed ammonia, water, and carbonic acid.

The crude sap joined to the carbon absorbed by the leaves is called the **elaborated** sap; and is now fitted to become part of the body of the plant. It does not remain in the leaves, unless the leaves, as in the leek and other fleshy leaved plants, are made into stores for the food with which next year's growth starts—a sort of vegetable capital. It passes out of them, along the inner bark in trees, or through the soft parts of the stem in herbs, and finds its way, downwards, to the very tips of the roots, and sidewards, to all parts of the plants. It is going down as the crude sap is going up; and thus there is a mixture of them in the tiny cells all through the plant. But the elaborated sap, wherever it is, is being made into some part of the body of the plant, or assimilated, as we say; while the crude sap must go on to be elaborated before it can be assimilated. This is very different from the manner in which blood is carried through the bodies of animals in two sets of vessels—the arteries carrying the blood which nourishes the body from the heart; and the veins carrying that which is unfit to nourish it, back to the heart. In fact, with the exception of what has been said respecting the breathing of a plant, and its product being the reverse of the product of the breathing of animals, there is but little resemblance between the life of plants and that of animals. Even in respect of breathing, there is contrast rather than resemblance. The most imperfect of animals has some part or organ the destruction of which destroys life; while the life of a plant seems to be spread through it all, so that any part being cut off, it will continue to grow, and even that part may be made in favourable circumstances also to throw out roots and grow.

We have seen how the seed grows, and how it is produced by the parts of the flower; and how wondrously the pollen is carried from one flower to another by water, wind, and insects. In a similar way the seeds themselves, after they are ripe, are wondrously scattered, and carried from one place to another, so that some are sure to fall upon ground good for their life and growth. Seeds, in almost all plants, are produced in immense numbers, so that if one fails to reach a favourable spot, others may. Some have wings, others, like those of the thistle and the dandelion, have a feathery tuft, that carries them lightly far and wide through the air. Those seeds that are born in capsules are thrown to a distance from the parent plant, by the sharp and sudden bursting open, or dehiscence, of the pod. Sitting on a summer day near furze bushes, we may hear the perpetual crackling of the opening pods; and we may often notice it, too, in gardens when the pods of pansies and balsam burst. If the seeds were to fall at the foot of the parent plant, and grow up there, the plants would choke each other, and none could grow well. Heavy and hard seeds, such as those of the oak and other trees, are carried by birds in their stomach, and dropped, undigested, in spots where they grow up far from their place of birth.



o, Opening valve; *pl*, placenta with seeds attached.

Fig. 29.—Seed-Vessels of Grass and Pansy.

Plants once begun to grow do not move from place to place, but yet they have in their separate parts a certain power of movement. The winds wave the branches, and play among the leaves; and thus aids the crude sap in rising, and helps to squeeze the elaborated sap all through the plant. Many flowers follow the sun's daily course; others turn from right to left, or from left to right daily; and if held by force from doing so, will die. Everybody has heard of the sensitive plant, how it shrinks from a touch. One taken in a carriage draws itself together when the first joltings begin; after a while it reopens, as if reassured. Yet even then, if any one touches it, it gathers itself together once more. There is a plant in India called the moving plant, the large leaves of which move slowly from side to side, while the small ones are constantly jerking towards and from each other.

Even in their death and decay, plants aid the life of the future. The vast plains of Africa and Asia are deserts because no water usually reaches them. Whenever water, by any cause, does reach them, then plants grow up from the decayed vegetable remains that cover the plains. The plains of France between the Seine and the Loire, during the long and terrible period of barbarian rule, became covered with dense forests. After the dreary centuries of the middle ages had passed, the forests were cut down, and then it was found that a rich soil had been formed by the leaves which had lain and rotted in them. Where these old forests were, is now the most fertile part of France. There are localities where the soil being nothing but chalk few plants will grow. But men plant pines in such places, for they will grow where almost nothing else will. The needles and fallen branches of these pines pile up as they fall, and in the end form a soil which it pays to till. Under the hands of industrious men these forests begin to blossom as the rose.

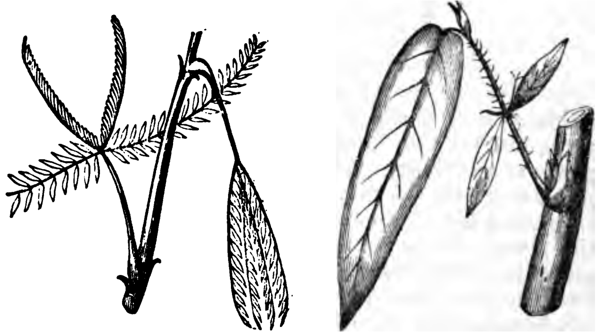


Fig. 30.—Sensitive Plant and Moving Plant of India.

Plants live by what they take from the ground and from the air; but in their death and decay they pay back to the ground more than they received from it; for they give it, besides the rest of their matter, the solid carbon which their fragile leaves, by the aid of the sunlight, had *taken from* the air.

CHAPTER V.

THE STRUGGLE FOR LIFE.

THE immense variety of kinds of plants and animals, that exist upon the earth's surface, has a meaning and purpose which it will be well for us to reflect upon; and the consideration of this meaning has of late become one of the most important parts of the study of natural history. Here, let us suppose, is a large piece of ground—ten or a dozen square miles in area—some parts of it sandy, others clayey, and some of it a rich loamy soil. On the richer part of it corn grows well; but on the sandy, or on the clayey parts it may be, none can grow. On the sandy parts, however, though not corn, other plants—perhaps pine trees—may grow, and on the clayey parts yet others. And the greater the varieties of ground in the area, the greater would be the variety of different kinds of plants which could find the means of life upon it. Even on the parts where the corn grows, there may be mixed up in the soil a number of mineral substances which corn does not require for its growth; between the blades of corn, therefore, there will be the means for other plants, or weeds, if you like, to live. A sugar planter plants maize or Indian corn between the stalks of the sugar cane for this very reason. If there had been only one kind of plants in the world—say corn—then very much of the surface of the world must have remained barren; and the great variety of plants means, that the great variety of soils and conditions of the air is put to use.

Here again is a tree—an oak tree let us say—on which a hundred different kinds of insects live. Some feed on the soft parts of the leaves, others feed on the veins of them, others on the bark, others on the wood within the bark, others on the roots, others on the flowers, others on the fruit; many kinds of birds, again, live on the different kinds of insects; many kinds of other animals live in their turn upon the birds. Had the tree been all throughout of a uniform substance, like one-celled plants and many kinds of sea weed, how should all this great variety of living things have been supported?

In the same way, we may see that the great variety of trees and smaller plants, which can live on any piece of ground, will enable a still greater variety of insects to live upon them, and a still greater variety of animals to live, which feed upon these insects. So that *variety* is the source of that wondrous *amount* of life, animal and vegetable, which we find in this world. The more varied a tree is in its parts, the more of the means of life it gives to other beings; but let us notice also the more means of life it has for itself. If its cells were only root-cells, then it could draw nourishment only from the ground; but since some of them are leaf-cells, it can draw nourishment from the air as well. And since some of them are wood-forming cells, its leaves can be held upright, high in the air. The greater the variety of its organs, the greater are its means of finding nourishment; and the better all its organs are adapted to their purpose, the more likely it is to live, and to leave others like itself to live after it. For if the cells which form the pistil were not well adapted to catch pollen driven about by the wind; or if some of them did not form honey, and thus attract pollen-covered insects to the pistil; then, however well the tree might thrive in itself with its root-cells and its leaf-cells, it could not produce seeds; and so the race of that kind of trees would die off from the face of the earth.

And the same thing is true of animals. The jelly-fish, which has scarcely any distinct parts—no eyes, no legs, no claws, no hard shell, and consists mainly of one uniform soft substance, cannot take the same care of itself as a crab can, which has all these separate parts. When the tide leaves the jelly-fish, it lies helpless on the shore and dies. But the crab is more likely, as the tide is leaving it, to be able to follow the receding waters, or if not, it will seek a hole covered up by sea weed in which to hide—drawing closer into the hole as it sees danger *approach.*

In truth, this variety of organs among plants and animals, by means of which each different plant and animal finds its means of life in different parts—some on water, some on land, some in the air, some as parasites on other plants and animals—is like the means by which mankind contrive to live in society—namely, by the division of labour. When one is a tailor, another a baker, another a farmer, another a mason, another a sailor, another a merchant, and so on, all can live better than if each one man did everything for himself. Even so, plants can thrive better when some of their cells are fitted only for sucking moisture from the ground, others from the air, and others only for support; when some become anthers, and others pistils: and the structure of animals gives the same advantage, when some cells form stomachs in which to digest food, others hands and claws to catch it, others legs to run after it, or to run away from enemies, others eyes to see food or to see foes, and so on. By this means the different animals can better preserve themselves from danger, more easily find food and pleasure, and leave behind them young ones to inhabit the earth when they are gone.

What, then, is the test of perfection in a plant or in an animal? Variety of organs. And this is what the naturalist judges in trying to classify the hundreds of thousands of both. He counts those least perfect whose organs are the simplest; and those most so that are the most highly endowed with varied organs, to fit them for different conditions and circumstances, to find most pleasures, and to avoid pains and dangers most easily. And in considering them all, both plants and animals, he finds a wondrous scale of being: beginning with the single-celled plants and animals in which there is no variation of organs—no division of labour; and rising up to plants of very high organization, and to animals endowed with bodily limbs the most active, and senses the most acute; till at last he ends with man, a being endowed with organs which fit him to live in every clime, with senses which enable him to draw pleasure and profit from almost every other product of nature; and, above all, endowed with an inventive intellect which adds to the sharpness of his senses, so that he can see and trace the movements of the stars, and tell their chemical nature; which adds, too, to the activity of his limbs, so that he can rush through the air with the speed of an express train; and even where circumstances prevent his personal movement, can make his wants known at the other end of the world by means of electric telegraphs.

But let us notice this. The variety of organization is adapted to the avoiding of foes and of pains, as well as to the seeking of what is useful and pleasant. What does this point out? That in the very variety of life, there is a variety of dangers. There is no plant but is preyed upon by animals or other plants; no animal but is preyed upon by other animals, and is liable to dangers from a multitude of causes—cold, hunger, accidents, disease. There is, in fact, a struggle for life which every separate animal or plant must go through; and according to its mode of conducting that struggle, according, that is, to the means which it has to conduct the struggle well—to the nature of its organs, bodily or mental—will be its success in securing its own life, and its chances of leaving others of its kind after it. A tree that has thorns which repel those that seek to injure it, or poisonous juices to make them avoid it; an animal that has strength to resist attacks, or cunning by which to trap its prey, and to hide from its enemies, as well as speed to catch the prey on the one hand, or to escape from the enemies on the other—such trees and such animals will succeed best in the struggle for life. But those whose organs are little varied—those whose limbs are sluggish and senses dull—those which can neither readily see what would be useful, nor easily flee from what is hurtful—they must succumb before the better organised. The world with its varied kinds of plants and animals is like a great battle-field, where the victory remains with the strongest, whether in physical force or mental power, and the weak must die. *Strength* and weakness, however, must be understood as meaning fitness or unfitness for surrounding circumstances; and thus the world may more properly be described as a great field of rivalry for the favours of nature, in which the fittest ever wins. The result, then, of the struggle for life is, that those who hold their place, by that very fact show themselves the fittest for it; and the end attained is this—a world peopled with the strongest races both of animals and plants.

It is not merely animals and plants of different kinds that struggle against each other. Those of the same kind are the most dangerous rivals to each other. In every field of wheat that is sown, all the seeds do not grow. Why? Because there is not room for them all. The weakest are starved, and elbowed, as it were, out of existence, the strongest grow up. Is it not so even with mankind? Who prosper most in the competition for positions in society? Those whose hands and brains are sharpest and energies most alert.

But success in the struggle for life is not merely one of force, not merely a result of the defeat of foes; plants and animals thrive best which best adapt themselves to surrounding circumstances, and can find among these circumstances most that suits their wants. In the almost endless chain of relations in which every living creature is bound, who shall trace every link of things useful and things hurtful? The clover plant, as has been pointed out, thrives best where there is the greatest number of humble bees to carry pollen to it. Its growth depends on the number of these bees. On what does their number depend? On the number of their foes. Among the most destructive of these are field mice, so that the fewer field mice there are in a district, the greater will be the number of humble bees, and the more plentiful the clover. On what does the number of field mice depend? On the number of cats in the neighbourhood; and it has been said, half in fun, half in earnest, that the number of cats in a neighbourhood depends upon the number of old maids. Now observe the chain of relations. On the old maids depend the cats—on the cats, the mice—on the mice, the bees—on the bees, the clover. Extend the chain: on the clover will depend the oxen which feed upon it; on the oxen will depend the strength and energy of the Britons who eat beef. On their strength and energy will depend the commerce and manufactures of their country. On that commerce depends the comfort of the British colonies, and of many other lands.

Thus great things and small are linked together in nature. The strong races are those which, from one circumstance or another, are best fitted to derive advantage from all their surroundings; the weak, those which, not being so well adapted, must die out. Nature selects, as it were, the strong races for continuous and prosperous existence, and thus the notion of what has been called the "struggle for life" leads to another which is usually spoken of as "natural selection," or "survival of the fittest."

Fig. 31.—Tropical Vegetation.

PART III.

THE ANIMAL KINGDOM.

CHAPTER I.

THE PARAGON OF ANIMALS.

"WHAT a piece of work is a man! How noble in reason! how infinite in faculties! in form and moving, how express and admirable! in action, how like an angel! in apprehension, how like a god! The beauty of the world! The paragon of animals!"

So wrote Shakespeare, and the last phrase is strictly true. A man is an animal. But this need not shock us, for it only means that he is a living being. He is the paragon of animals. This means that no other comes up to him in perfection of structure. The greyhound may excel him in speed, the lion in strength; but take him for all in all, no other animal is so perfectly adapted to surrounding circumstances. He thus assumes the highest rank in the animal kingdom.

The skeleton of a human being has three main divisions: first, the skull, like a large round box; second, the body or trunk; and third, two pairs of limbs formed by the arm and leg bones. The middle line of the body is formed behind by the back-bone; before by the sternum or breast-bone. The back-bone is made up of a series of thirty-three rings, all pretty like each other, and capable of moving a little, one upon the other. Each of these rings is called a vertebra. The seven uppermost form the bones of the neck. Each of the next twelve sends off, on both sides, a rib which projects forward toward the breast-bone. The ribs, the vertebræ, and the breastbone, form a sort of cage, in which are packed up certain organs.

The space between the ribs and the back-bone is called the **thorax**; the space in front of the back-bone, below the thorax, is called the **abdomen** or belly. The thorax is separated from the abdomen by an umbrella-shaped membrane or tough skin, called the **diaphragm**, which stretches across from the breast to the back-bone; and it is easy to see that if, by any means, the curve upwards of this umbrella-like diaphragm be straightened, the thorax will be so much the roomier.

In the thorax, between the lungs, lies the heart. The lungs hang at the end of the **windpipe**, which comes down the front part of the neck, at the top of which it opens into the back of the mouth, and also into the passages which lead to the nostrils. Immediately behind the windpipe there is a soft tube called the **gullet** or œsophagus, lying against the vertebral column. This begins at the back of the mouth and passes down the neck and thorax through the diaphragm into the abdomen. It then swells out into a large bag called the **stomach**; and narrowing again below the stomach, forms the bowels or **intestines**. These are folded many a time upon themselves, and receive different names in different parts of their course. The gullet, stomach, and intestines, thus form a long winding tube passing from the mouth through the trunk. In the sides of the mouth are six small fleshy bundles, called the **salivary glands**, which form the saliva or spittle, and pour it into the mouth. There it mixes with the food, and helps to turn the starchy part of it into sugar.

In the abdomen lies also the organ called the **liver**. It is close under the diaphragm, and forms a fluid called **bile**. There, too, lies the **pancreas** or spleen, which produces a fluid called the **pancreatic juice**. The teeth, salivary glands, gullet, stomach, bowels, liver, and pancreas, all join to perform that work upon our food which is called **digestion**. The teeth grind the food as a chemist pounds the solids which he wishes to be easily dissolved; the salivary glands moisten it with their peculiar liquid; and, being swallowed, it passes through the gullet into the stomach. Now, from the mouth to the extremity of the bowels is one long tube. How shall the food get out of it into the body? On one condition, the same as that on which food can be absorbed by the cells of plants; namely, that whatever we eat shall become liquid. It can then get through the walls of the bowels into the body by the process of osmose. What we drink can be absorbed easily. Those solids also that are soluble are dissolved as they pass on, by the juices of the stomach; and the starchy

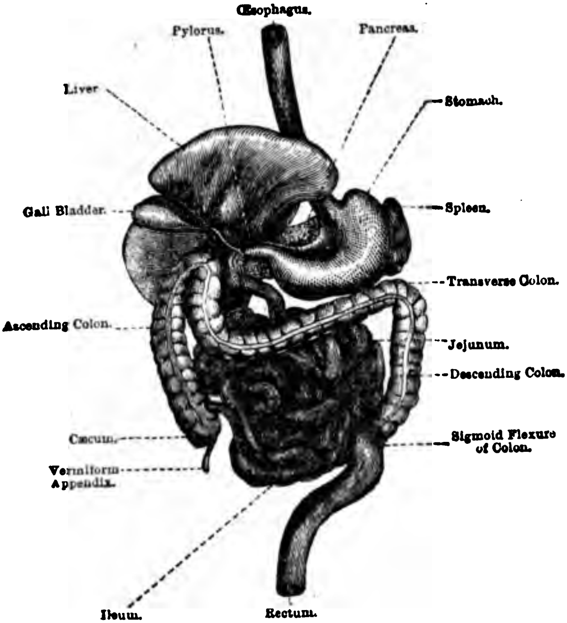


Fig. 32.—Liver, Stomach, and Bowels.

parts of our food are acted upon first by the saliva, and again by the pancreatic juice. These two liquids have the property of turning starch into sugar; and sugar is easily dissolved.

The substances, however, that are of a harder nature, such as the albumen of which lean flesh is mostly formed, are acted upon, in the stomach, by a juice which is formed there called the **gastric juice**, and this converts them into a fluid. The fat, or oily parts of our food, are worn down, as it were, by the pancreatic juice into very fine granules—so fine that they can pass through the membranes of the bowels. In this state all our food is absorbed; one part of it goes directly into the blood-vessels of the stomach and intestines; the rest of it, called **chyle**, is taken up by numerous small tubes called **lacteals**, which at last join all into one tube called the **thoracic duct**. This carries the chyle to a certain large vein or blood-vessel near the heart, and pours it into the blood, with which it mixes.

But besides food, air must be mixed with our blood before it becomes capable of nourishing the body. This is done in the lungs. The windpipe and lungs may be compared to a tree and its branches, every part of which has been hollowed out, as insects hollow out trees at times, leaving only the outer bark. The windpipe is the trunk growing from the back of the mouth into the thorax; the countless divisions into which the windpipe divides are the branches; and as each branch ends at last in a small hollow cell, these cells may be called the leaves. Think of all these hollow leaves or cells joined closely up and pressing against each other, so that the fine hollow branches and hollow leaves form one spongy mass, and you may have an idea of what a lung is. Now, the air we breathe passes from the mouth into the windpipe, and from that into its hollow cells. It passes through the walls of these into, and through, the walls of the fine blood-vessels that interlace among the lungs, and so the oxygen of it becomes mixed with the blood. At the same time, the useless matters of our bodies which are mixed with the blood in the lungs, pass out of the blood-vessels into the air-cells of the lungs, and are breathed out from them in the form of carbonic acid gas. This process of breathing in oxygen, and breathing out carbonic acid gas, is called **respiration.**

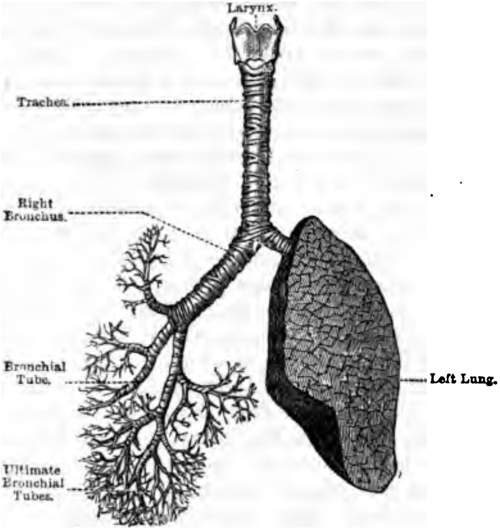


Fig. 33.—The Lungs.

Let us now consider the course which the blood takes through the body—which is called its **circulation.** The large vein into which the chyle is poured from the thoracic duct is formed by the union of all the veins from every part of the body. Veins are vessels which carry the blood to the heart; and this large vein carries its mingled contents of chyle and blood there. The heart is a kind of thick fleshy pouch, with four compartments; two called **auricles,** and two **ventricles.** The blood enters the right side of the heart, which then contracts and forces it forward through blood-vessels that go out from the heart to the lungs. These blood-vessels branch off into exceedingly fine tubes, which twine themselves about the fine cells and tubes of the windpipe, like ivy round the branches of a tree. In them the oxygen from the lungs mixes with the blood; and then they begin to join once more into larger vessels and form what are called the pulmonary or **lung veins.** By them the blood, which is now mixed with chyle and air, and of a red colour, is carried once more to the heart, and enters it on the left side. Before it had entered the lungs it was of a dark purplish colour. The heart contracts once more on receiving it from the pulmonary veins, and sends the blood off again, but not to the lungs. It goes now through every part of the body, in vessels which are called **arteries.** They carry the blood from the heart, and divide continually, like the branches from the trunk of a tree, till at last they become so small that they are invisible to the naked eye. They press into every part; into the flesh, skin, hair, bones, lungs, liver, even into the heart itself, and into the white of our eyes, as can be plainly seen when the eye is inflamed. The blood goes along these arteries and gives off to every part the nourishment it needs. It repairs for the flesh the flesh that has been worn out—for the nails the parts that have been cut off; it adds hair to the hairs—bone to the bones—skin to the skin. Every organ gets what it requires. And all this is done without mistakes. Bone is not made where flesh should be—eyes are not made where ears should be—nor nails where hairs should be. From the same red blood all our different parts are made. They each get the one thing they need and nothing else. A particular kind of lime is laid down by it in the teeth—and a different kind as it passes through the bones. But this is not all. The blood as it goes back to the heart, by the veins, is not idle. It takes up and carries away from every organ the parts of that organ which are worn out and henceforth useless. It takes these to the parts of the body which are the natural outlets for useless matter—to the skin, where it gets off as sweat, which is a mixture of water and fat—to the lungs where we breathe it out—and to the organs called **kidneys,** where it gets off as urine.

Thus the bones of the skeleton form a framework for the support of the organs of respiration, circulation, and digestion. But the bones cannot move themselves. They are clothed with flesh, called **muscles**; and this flesh is formed of fibrous or thready pieces—the fibres laid lengthwise together. Each separate muscle is joined to the bones by tough ends called **tendons**. When these muscles contract, they move one or more of the bones to which they are joined. The bones which play upon each other, are drawn one way or another according as the muscles pull them, or leave them free. The muscles are covered with skin, and this in some parts is overgrown with hair. In all these respects the paragon of animals differs but little from other animals whose organization gives them a high place in the scale of living beings.

But there remains one set of organs, in regard to which, while he is like these animals in some respects, he is much more finely and perfectly organised; namely, the nerves. The tube which is formed by the vertebral column is not empty; neither is the hollow box formed by the bones of the skull. The skull is filled with a large mass of marrowy-looking matter, partly white and partly grey, called the **brain.** The grey matter, which consists of a heap of excessively small cells, overlies the white matter which is formed of bundles of exceedingly fine threads. The hollow through the chained rings of the back-bone is filled with the same substance continued from the skull downwards; but in this hollow it is in the form of a round white cord, in the middle of which is a cord of grey substance. This is called the **spinal cord.** Then from the holes between the vertebral rings the spinal cord sends out branches like white threads, which spread themselves all over the body, and branch off into every organ till there is no part without its nerves, as these threads are called. To prove that they are everywhere on the surface of the body, you may try on what parts you could press the point of a needle and not feel pain. For it is by means of the nerves that we feel, and indeed hear, see, taste, and smell. Without them we could never know that there were such things as can be felt, seen, heard, tasted, or smelt. It is by means of the nerves, too, that we move; for though the muscles are the instruments of movement, it is the nerves which set them in motion. The brain and nerves then, are the organs of sensation and motion. The nerves that proceed from the brain to the eyes convey to the brain what the eyes see; those that go to the tongue and palate convey what is tasted, those that go to the fingers and body convey what is touched and felt; and, in a way mysterious and unknown, the mind receives from the brain all the information so conveyed. When the mind resolves upon some movement of any part of the body, then in the same mysterious way the resolve affects the brain; the brain affects the nerves, and the nerves move the muscles concerned in performing the motion resolved upon.

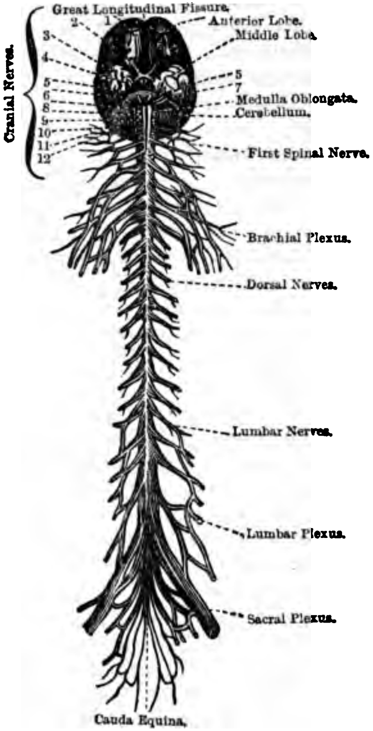


Fig. 34.—Brain and Nerves.

Nerves are found to consist of bundles of fibres of two kinds; one for carrying information from the senses to the brain, called the **afferent** fibres; and another called ***efferent*** fibres, for conveying resolves or orders, so to speak, from the brain and mind to the different organs of the body. Suppose, for example, that a man is going on a journey by rail; and that, as he approaches the station, he hears a bell ring. In this case, the afferent nerves from his ears convey to the brain the impression of a sound. The brain, the organ of the mind, judges from this sound that a certain action is needful if its owner is not to be too late; and, by the efferent nerves, sends out to the legs the order to run. Of course we say, and say rightly in common language, that it is the man himself who hears the bell and runs; but the brain, the nerves, and their servants the muscles, are the organs by which he does so.

If, then, there be any animal whose feelings, as conveyed by the nerves, are always true impressions, representing what is actually going on around it, and whose brain always conveys the right order at the right time to do what the things going on require to be done; whose muscles and limbs are so formed that these right orders will be always obeyed at once and exactly; then such an animal must be well able to learn of approaching danger and to avoid it, to see a coming opportunity of pleasure or advantage, and to seize it; such an animal, in fact, must become head over all others which have less perfectly working brains, and nerves, and muscles. Such an animal is man.

CHAPTER II.

PROTOZOA AND RADIATES.

THE Animal Kingdom contains about 400,000 different species or kinds of animals. These are divided into five great sub-kingdoms. The first, and highest, includes animals with skeletons inside their bodies, and back-bones, such as man, a dog, an eagle, a herring, and a frog. These are called vertebrated animals, or **vertebrates**. The second includes jointed animals, whose skeletons or hard parts are on the outside of their bodies, and are in many segments, or separate but similar parts. These are called **articulates.** The third sub-kingdom includes soft animals, or **molluscs**, such as snails, oysters, and cuttle-fish. The fourth contains animals whose organs surround a centre, which is the mouth, like radii springing from the centre of a circle; such are jelly-fish, star-fish, and sea-urchins. This division is called that of **radiates.** The fifth division is called that of **protozoa**, or first animals, because those included in it are regarded as being the earliest forms of animals. The lowest kinds in this division are mere cells, or masses of cellular substance.

Each of these five sub-kingdoms is again divided into **classes**; the classes into **orders**; the orders into **genera**; the genera into **species**; and the species into **varieties.** The animals composing these different groups are all liker each other than they are like those of any other group of the same rank. The likeness between those of the same species and varieties is so great that we could have no difficulty in believing that they are all descended from the same original parents.

Let us commence with the lowest of these sub-kingdoms, and follow up what is called the scale of animal being, till we come again to man at the summit. At the bottom of the scale lie the protozoa, and only a little higher are the radiates.

The **Protozoa** are mostly so small that it requires the use of a microscope to see them. Some live in the bodies of other animals, the rest in water. The very lowest of them, the simplest of all forms in which animal life is seen, are but small masses of jelly, of no shape, or rather of a shape which is always changing. They are often like small round drops of oil, the outer part of the drop being a little thicker than the rest; and in moving they push out a part of their oily mass so as to fasten on anything in the way, and drag the rest of their body forward by means of this. When a small object is in the way, one of these masses spreads itself over it like a *drop of oil* or jelly, and digests it. Any part of their nass can serve them for a leg, and when drawn back ecomes again a part of the body. Such animals are alled by a name which means "root-footed."* One of hem, called the sun animalcule, does not move, but preads out long thin oily rays, like a spider's web. very light thing which touches these rays is caught, and mall water fleas so caught are compelled somehow to lide along the ray till they sink at last into the oily ody, and are gradually digested.

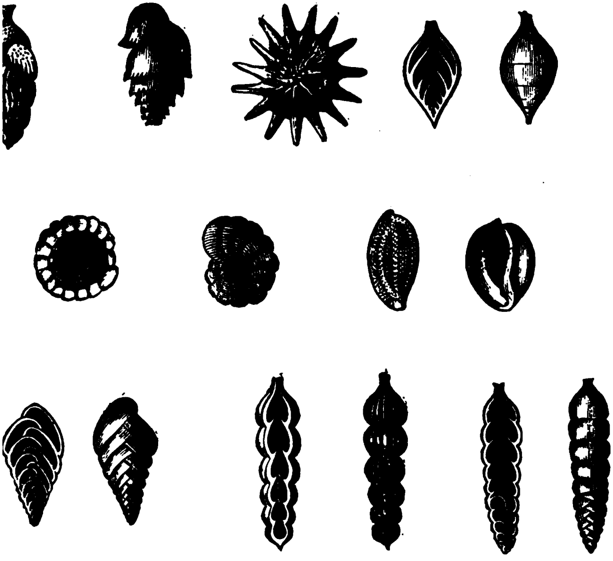


Fig. 35.—GROUP OF FORAMINIFERS.

Another division of the protozoa have round their jelly-ike or oily bodies beautiful minute shells, through holes n which they stretch out oily threads, forming a web round them to catch their prey. Although these animals re so small that they cannot well be seen without a nicroscope, yet they form whole strata of the earth. The sand of the sea-shore in many places consists mainly of their shells, and we tread over it regardless of the countless lovely forms beneath our feet. Their name, meaning "hole-bearer,"* is given them because of the holes in their shells.

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* Rhizopods.

Smaller even than these, and much more varied in their structure, are the little animals called "infusories," because they are found in water in which decaying substances have been infused. Their existence was never dreamt of till after men had invented the microscope. A single drop of water may contain 500 millions of them. They swarm in all pools and ponds and lakes and seas. Some are bell-shaped, others trumpet-shaped; and they swim about by means of hairs, or **cilia**, which they move incessantly. The motion of these cilia also brings currents of water into their tube-shaped mouths, carrying with it particles of floating matter for their food. The infusories form food for small fishes; and there are strata of the earth many feet in thickness, every cubic inch of which contains myriads of their remains.

The sponge with which we bathe ourselves is what once formed a horny kind of skeleton for a mass of jelly-like animals of the lowest kind. It is got in the sea on the coast of Syria and the Bahama Islands. When in the sea this framework or skeleton was covered over with a jelly-like mass. This was the mass of living animals. The sea water was drawn into the living sponge by the action of the cilia. It came in at the small holes, carrying such food as the animals needed, and was thrown out by the larger holes, after having been sifted of its digestible matters. A mass of sponge with its holes for water to go in and pass out, and the passages between them, has been compared to a city built in the water. The cell-formed animals along the passages are like citizens, who stand in the street, seeking a passing chance of getting food. These citizens, however, form their city from their own bodies out of the food they eat.

The sub-kingdom of **Radiates** is often called that of zoophytes, which means plant animals, because many of them resemble flowers in form, each division or ray

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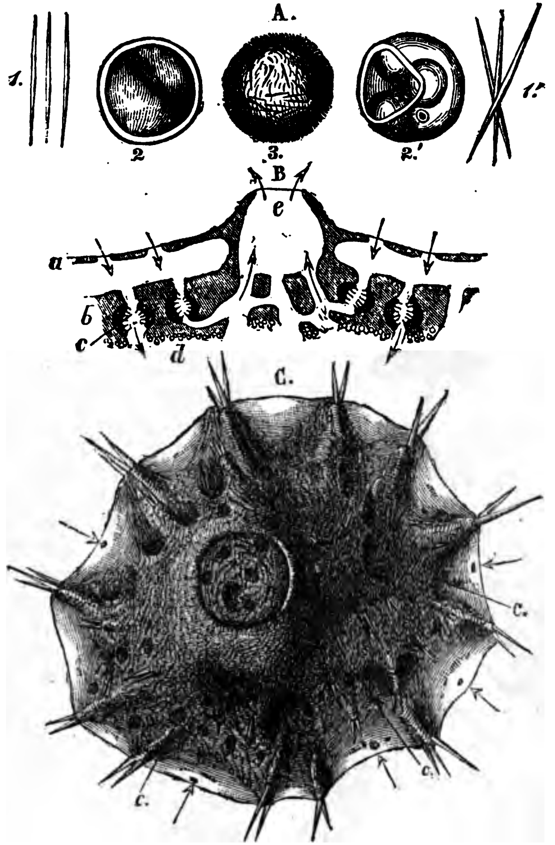
* Foraminifera.



1, 1′, Limy spikes; 2, 2′, 3, sponge seeds or cells; B, plan; the arrows show how the water flows in through *a*, *b*, *d*, and out at *e*; *c*, cilia; C, mass of sponge; *s*, holes by which water enters, leaving by those in the middle.

Fig. 36.—SPONGE.

being like the other, and all of them grouped round the mouth in the centre. They are divided into two classes, **polypes** and **echinoderms**, that is, many-footed and prickly-skinned animals. In the protozoa we found no other organs than a mouth and cilia; in the radiates we find a stomach and long arms, or feelers, to catch food with, not merely outstretched masses of jelly to which prey might stick. There is thus a somewhat higher preparation for enjoying or resisting surrounding nature.

A **polype** is an animal which consists wholly of a bag, or stomach, and a mouth, with many long thread-like feelers, or tentaculæ as they are called, round it. It can stretch them out, draw them back, and move them in different ways; and, it is said, can sting the infusories and other tiny prey which it catches. After it is caught the prey is carried direct to the bag, thrust in, and digested. One of the most simple and common of the polypes is the fresh water hydra, which is only a small jelly-like tube, with long arms from one end; and the other fastened like a sucker to a leaf, or a small piece of wood. It is so small that it cannot easily be seen; but may be got like fine strings on the floating leaves of water plants. It can be turned outside in, and will digest food as well by the outside as by the inside of its bag. It can be cut in pieces, and each separate piece will grow into a new animal. A young hydra grows from the body of an old one, like a branch from the trunk of a tree, and at a certain

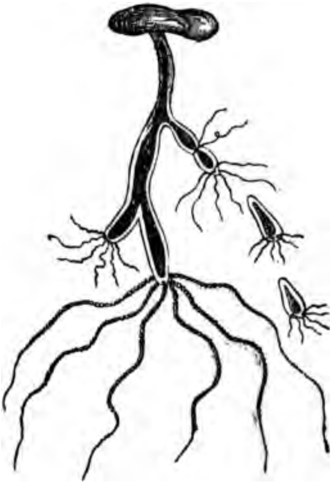
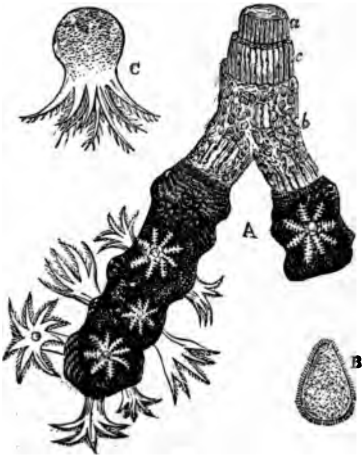


Fig. 37.—Fresh Water Hydra.

stage of its growth will break off and become a distinct animal.

When a hydra walks along a leaf it fixes the sucker end of its tube tightly on to the leaf, stretches its body till it lies like a straight line on the leaf; then holding on by the feelers, it draws the other end up to the mouth, and stretches itself anew. In a long summer's day it may even get over a journey of eight inches. The hydra acts with its long feelers, like a fisherman with a rod catching flies or small water beetles; and is so expert, that its prey once touched never escapes.

But there are polypes of the same nature as the hydra, which do not walk about, and the buds of which do not separate from their plants; they remain fixed to each other generation after generation, and form a tree of animals—a compound animal. They, like the sponge, form a horny skeleton for their support, which has the appearance of a tree or bush covered over with fleshy matter. This fleshy matter is starred, as it were, with what appears like flowers, but is in reality the feelers of the little animals waving in a circle, the centre of which forms the mouth and stomach. The Venus' fan is the horny remains of such a colony of animals. The common red coral is the skeleton of a similar colony. This animal fixes itself young and soft on the bottom of the Mediterranean sea; it grows up; others bud from it and do not separate; till at last a



A, branch with polypes; B, C, germs; *a*, inner stem of red coral.

Fig. 38.—CORAL.

branching mass is formed of polypes with open mouths and waving feelers. The soft body as it grows up forms in its inside a layer of carbonate of lime of a fine red colour, which is the stem of fine red coral running through the whole. Coral fishers with drag nets break off the branches, let the polypes putrify from off the stem, and then they have the red coral.

The greater part of the other polypes of this kind form stony or limy skeletons, much coarser and less valuable than that of red coral; but they claim our attention from the large masses which they form. There are very many kinds of them. The chief one is that called madrepore, which forms a special skeleton for each little animal, as well as for the whole mass, so that the animal lies in a kind of cup divided by a number of limy partitions going from the centre to the sides. Out of this cup it waves its feelers, and the mass looks as if it were a heap of living moving flowers. The madrepores, or white corals, spread themselves continuously over large areas. One generation dies and leaves its limy skeleton mass, upon which others perch and grow, so that large islands and reefs, hundreds of miles long, are formed under the sea. Such reefs and islands, formed by one race of polypes upon another, are like the cities in which the modern English live, over the remains of Saxon cities, which were built over the remains of Roman ones—which were built over the ruins of collections of British huts.

There are yet other kinds of polypes which do not form any limy or horny skeleton, and are therefore soft and jelly-like throughout their bodies. By their lovely colours and strangely formed feelers, they look like flowers in the ocean, and are called sea anemones. They form the prettiest ornaments of an aquarium. They are plentiful enough on the shores of Great Britain, but they grow much larger and lovelier in tropical seas. A sea anemone, one of the **actiniæ**, as they are called, meaning rayed animals, is a thick fleshy or jelly-like tube, the one end of which is attached to a rock or other fixed object, while the other is surrounded by circles of tentacles, like the corolla of a flower. The moment a tentacle is touched they are all drawn in, and a cone-shaped lump of jelly only is seen. These animals hold so firmly to the rocks that they may be torn in pieces, but cannot easily be got off whole; and yet they can crawl slowly along, or float away when they please.

Among the polypes also are the class of animals called sea nettles, or jelly-fish, or **medusæ**. They are those beautiful umbrella-formed crystal-like jellies which float about, steering themselves by waving rows of fringes. They are the parents of animals which were once thought to be of a different kind. In fact, they give birth to polypes which fix themselves to rocks, and then, after undergoing many changes, produce in their turn the floating medusæ. Still more striking in its nature is the little floating pink and blue coloured Portuguese man-of-war, which, instead of being one animal, is in fact a colony of different little creatures all fed by one stomach, and nourished by one circulating fluid; some doing the work of steering, others acting for the common defence by stinging; others feeding and forming juices to nourish the community, and others producing eggs—a true living republic. The eggs, when produced, give birth to new colonies.

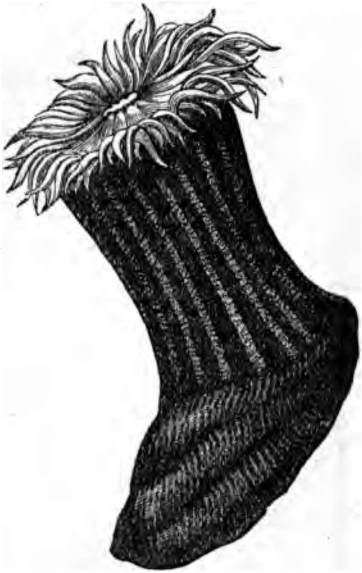


Fig. 39.—Sea Anemone.

The **echinoderms**, or prickly-skinned animals, are a division of the radiates, so named because of their rough, tough skins or shells; besides which they have often long spines. There are three chief kinds of them—star-fish, sea hedgehogs, and sea cucumbers.

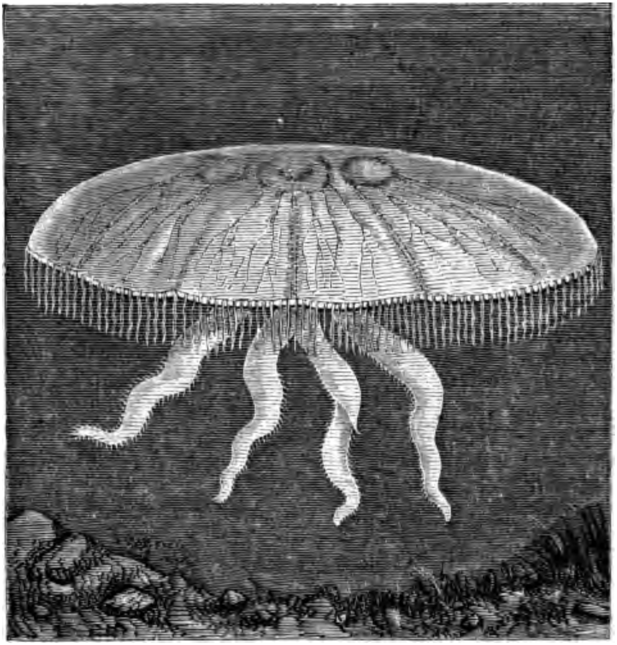


Fig. 40.—JELLY FISH.

Almost every one has seen a **star-fish** with its five rough rays, reddish-brown on the top surface, whitish below, and little holes all over. Many a one has lifted a star-fish, but fewer have watched it move. On each ray, on the under side, run grooves in the skin along each side of a bony ridge, through which small holes are pierced—as many as three hundred in each ray. The animal when it wishes to move, can push a soft jelly-like foot through each of these holes; this it does by injecting water from cells in its body into the parts about the holes. With these feet so thrust out it can hold on to what it touches and drag itself along. It is worth while picking up a star-fish from the shore, and laying it down again in the water on its back. It pushes out hundreds of little feet trying to catch something to right itself with; and gradually turns over one ray till it gets the point of it on to the sand, or rock. This effected, it soons gets all its body into the right position, and takes itself off. Or better still, and less cruel, one may be put into a tumbler of sea water, and watched as it climbs up the sides with its hundreds of suckers. With these it catches small crabs and cockles, and drags them into its mouth. It clings. too, round oysters—puts its mouth close to the edges of the joined oyster shells; and, so they say, drops a fluid upon these edges which soon causes the oyster to open and yield itself a prey. When a star-fish loses one of its rays a new one grows. There are some called brittle stars, which break themselves into small pieces whenever they are alarmed.

The **sea hedgehog** is in the form of a shell-ball, covered with bristles or spines. If you fancy the five rays of a star-fish bent up so as to meet in a centre and form a kind of globe, you get an idea of the shape and nature of this animal; but it has ten rays, five large and five small. The five small rays are full of little holes through which it can put forth hundreds of fleshy feet. Long spikes, sharp as a needle at the point, and cup-like at the base, so as to play upon rough knobs on the skin or shell, are so fixed that they can be set up or laid flat as the animal pleases. The box is formed of many shelly plates all curiously joined, and fitted so that they can grow larger, without any of them being removed. Over this is drawn the tough skin with the prickles or spines. Thus well defended, the soft animal lies within its shell and pushes out its suckers. The mouth is formed of several shelly bones, surrounded by fringes which serve as lips; and there are five strong teeth or jaws at the opening which rub against each other and grind the food. The greater part of the shell is filled with the long rolled up bowels of the animal; for it eats vegetable food, sea weeds, and the like, which take long to digest. When the animal moves it seems to roll, for the suckers of one layer being fastened to the rocks drag round the next layer, and these drag the next round, and so on. It moves into the sand cleverly by means of the spines. —keeping the central ones up round its mouth, joined so as to form a tube; thus, as it buries itself, it leaves an opening in the sands for air and water to flow in to it. With shell, spines, feelers, and teeth, we have here an animal which is well equipped for its part in the struggle of life.

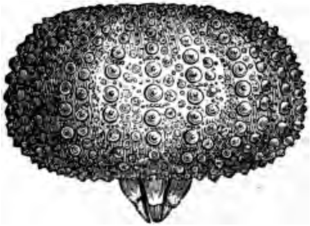


Fig. 41.—Sea Hedgehog.

The **sea cucumbers** have no shell, but only a skin thick and tough, and mixed with limy particles. They get their name from their cucumber-like shape. Through holes in their skin, they can push a number of short soft feet. The mouth is formed of several projecting pieces of a shelly nature. One kind of them, called the trepang, is eaten by the Chinese. The kind called the synapte has a skin formed of the most beautifully marked fine plates; and, when it is starved or irritated, will break itself into pieces.

CHAPTER III.

MOLLUSCS AND LOWER ARTICULATES.

THE **Molluscs** owe their name to their soft substance, *such as that* of the common snail. Some of them shut themselves up in a shell, which they make out of the slime secreted by their own bodies. Many of the shells are exquisitely beautiful. The study of them is called conchology, or shell-lore. But the shell is one thing, the animal another; and the animal belongs to natural history. Among the molluscs are included—first, the sea mosses * — second, the coat-bearers † — third, the headless molluscs ‡—fourth, the wing-footed molluscs §

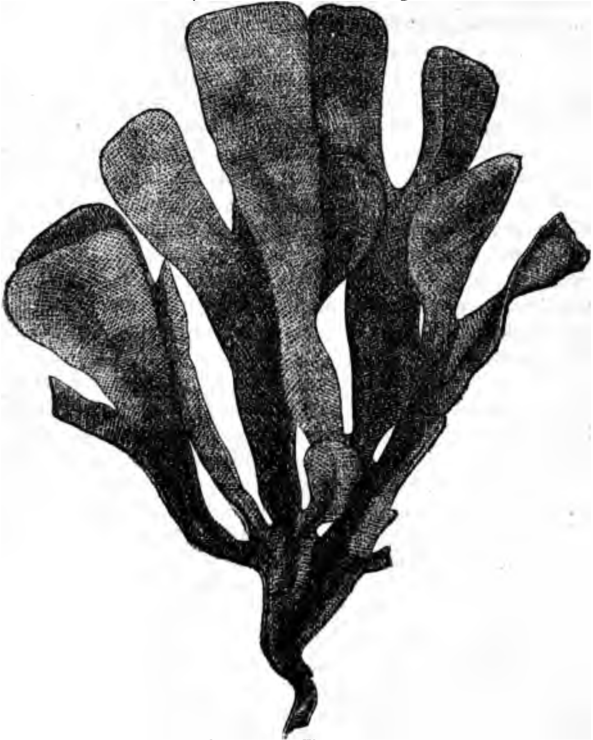


Fig. 42.—FLUSTRA.

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* Bryozoa. † Tunicates. ‡ Acephals. § Pteropoda.

—fifth, the belly creepers*—and sixth, the head-footed molluscs.†

The **sea mosses**, or as they are sometimes called, sea mats, are very small. They cover sea plants with a velvety greenish kind of matter, that at first looks like a parasitic moss. It is, however, a mass of animalcules, with cells set close together, like those of bees. These cells are horny and crusted with limy particles. They sometimes appear like a fine lace on a leaf of sea weed. There is a sea mat found on the shores of Scotland, of which 1800 cells stand on a square inch; and another, called the leafy flustra, forms a leaf with twice that number on the same area. This leaf is not that of a sea weed, however, but is formed by the sea mosses themselves, which build their cells back to back, like honeycomb. Out of each of these shells come hundreds of waving arms, at the end of which are cilia, that keep the water in motion and bring food along. Each animal eats for the whole, as well as for itself. A microscope is required to see these animals. Some of the shells have lids which the creatures can shut up when they have eaten enough.

The coat-bearers, or **tunicates**, or sea squirts, as the best known kinds of them are called, have a body covered by a tough skin in the form of a double-necked bottle; the opening of the one neck admits water and food—that of the other throws out the products of digestion. From having these two openings the tunicates, as well as the sea mosses, are higher animals than the radiates, which receive their food, and reject the refuse by the mouth. The opening which forms the mouth leads to an inner bag or stomach, in which are cilia that wave continuously and cause a current of water to pass through the body, from which the food is sifted. This bag and its hairs serve to bring air to the animal, so that a kind of respiration, as well as digestion goes on in it. Their blood is colourless, and does not circulate, but passes backwards and forwards, or oscillates, through the same vessels.

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* Gasteropods. † Cephalopods.

The sea squirts * are so called, because when they are squeezed they squirt water out from the openings in their bag. Some are fixed to the rocks; others float about. One kind, called the salpa, floats in a long transparent chain of animals, and forms ribbons of light in the sea by night. The chain breaks when it is lifted out of the water. There are also single salpæ found—and it has been discovered that the chained animals produce the single ones, while the single ones produce chains. Thus a salpa parent differs from its child, and the reverse. Grand-children, so to speak, resemble their grand-parents, not their parents. This is called alternate generation.

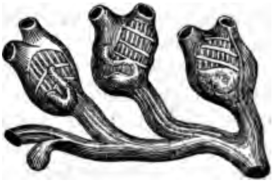

Fig. 43.—ASCIDIANS.

The headless molluscs, or **acephals**, of which oysters and muscles are examples, have a very complete digestive set of organs, though they have no head. They are mostly what we commonly call shell-fish. Their young are soft, and float about at first; then settle down on the rocks and secrete or sweat out a shell for themselves, in two distinct parts or valves. These valves or lids, as we may say, are joined by a tough muscle, which may be seen in the oyster or the mussel; and almost the only sign of life one can notice in an oyster is the opening and closing of these valves. When open, water is brought into and passed out of the shell by means of cilia, which the animal moves. The outer skin of the oyster which lines the shell, and from which, indeed, the shell is secreted, is called the mantle.

The mussel binds itself to stones or pieces of wood by means of strong threads. It can thrust out what is called a foot, in which there is a groove; and at the inner end of this groove it secretes a kind of gum, which it can press along the groove. When anchoring itself by threads, the mussel thrusts out his foot rolled, so as to form a tube, presses it firmly against the stone, lets the silky gum from the tube stick to it, then slowly withdraws the foot; while the gum hardens and forms a thread. It gives a jerk after making each thread, as if to try how strong it is.

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* Ascidians.

The cockle creeps by means of a similar foot, and buries itself in the sands. It does not anchor itself like the mussel. It can thrust out a couple of tubes, like horns, on which there are said to be eyes. There is another mollusc called the pholas, which is as pleasant to eat as an oyster, and which does a work not easy to understand. It bores into the hardest rocks, and makes a hole in them for itself and its shell, in which it can live fearless of all foes but man.

Pearl oysters secrete the pearls, for which they are so much prized, in the same way as they secrete their shells. If any hard body get among their soft flesh—as for example a grain of sand—then, it is said, they begin to lay some of the matter which would otherwise have lined their shells round this hard body, perhaps to make it smoother and less hurtful to themselves, and this forms a pearl. The Chinese, it is said, knowing this, open oysters, thrust in a grain of sand, and get a pearl after a year or two. Two-shelled molluscs like the oyster and the cockle are called bivalves. They breathe by platy layers forming a kind of comb-like gills; and are called sometimes by a name which means plate-gilled.*

The wing-footed molluscs are very small, and abound in millions in the sea. They are the winged insects of the ocean.

The belly-creepers or **gasteropods**, of which the snail is a well-known example, move on a flat disc. They have small heads, which, however, can hardly be said to be distinct from the body. Many of them have four tentacles or feelers: we all know those of the snail, and how quickly it draws them back when touched. And no wonder, if, as is said, the bright black spots at the ends of the two largest feelers or horns be eyes. Some breathe air, and live on land, like the garden snail; others live in water only, and breathe both by gills and by lungs. Some have shells, others have not. Snails become torpid during the winter, and lie hid in the ground, or in holes, snugly drawn up into their shells. In some places they are eaten, either as food or medicine.

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* Lamellibranchiates.

The head-footed molluscs, or **cephalopods**, get their name from the belief that eight or ten limb-like projections around their heads were real limbs used for swimming; but they are only tentacles or feelers. They swim backwards with ease, by driving forcibly out from their bodies the water which they have used in breathing by their gills. They have strong tough skins, and good eyes. Their feelers are provided with strong suckers on their front surface, by which they cling tightly to whatever they fasten upon. They have a firm chalky looking flesh, and some have shells. They have nerves and a distinct kind of circulation. They are, in fact, the most perfect of the molluscs. The cuttle-fish, an animal of this order, has a broad chalky bone in its body; and an ink-bag, from which, when alarmed, it pours a dark fluid, that makes the waters around it black. From this

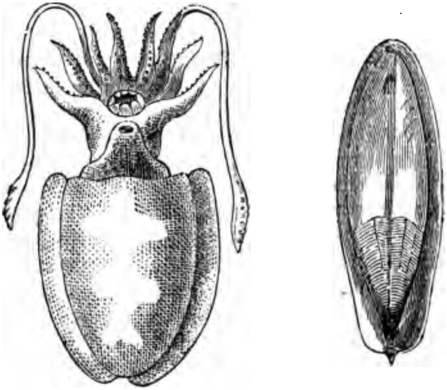

Fig. 44.—CUTTLE-FISH AND CUTTLE-BONE.

bag we get the colour called **sepia.** The octopus or poulpe is a more terrible animal of the same kind. It is roundish in shape, has large eyes, and very long feelers. Its suckers act like strong cupping glasses. If it once touch its prey, it keeps tight hold. It will cling to large fish, and even men; and must be killed before it can be taken off. The pearly nautilus, which floats in its shell as in a boat, and expands its tentacles like sails, is also an animal of this order.

The animal sub-kingdom, usually placed next above the molluscs, is that of the **Articulates,** or jointed animals; so called because they have bodies made up of a series of similar parts, joined together, and forming so many segments. Each segment forms a kind of ring; soft, it may be, like the rings which make up the long body of a worm; or hard and shelly, like the segments of a lobster. Among the lowest of them are those long worms which live in the intestines of other animals.* A little higher is the division to which the common earth-worm and the leech belong.† The leech can stretch the rings of which its body is formed, so as to be five or six times longer at one time than another. At each end it has a sucker. At the mouth end, in the middle of the sucker, are three jaws or teeth with which it bites the skin through before it sucks the blood. Extending along its body, over the rings, are an immense number of muscles, which form the walls of its body. These are moved by nerves that radiate from a series of small knots of nervous matter that lie along within the body like a string of beads, and are called **ganglia.** The largest knot is at the head, and forms a kind of brain; so that even here we see the beginning of a higher organization.

The common worm is in every respect well fitted to live underground. There are about 120 rings in its body, which at the mouth end are small and fine; while at the hinder part they are flattened above and below. The mouth is a round hole, with a kind of upper lip for putting earth into it. The worm eats earth, but probably

* Helminthes. † Annelides.

for the nourishment got from vegetable matter it contains. On each ring of the worm are four little bristles which point backwards; by means of these it fixes itself in the ground, and cannot be pulled out of its hole by any one getting hold of its tail. It will break rather than be torn out, thus losing its tail; but that is of no great consequence, for it will grow again. Worms that live among the sea sand have strong bristles projecting from their sides, which serve them as feet. The nereis is a kind of worm which can stretch its rings so as to measure thirty feet in length, and then contract them so as to be no more than eight feet long, as it lies quietly on the sand. It is one of a kind which breathes by tufts or gills placed on the rings along its back.* Some of the sea worms have a sticky moisture on their skin, by means of which they glue bits of shell, straw, and wood together, and form a tube in which to live.† Others form a case of lime around themselves. Often, sticking to stones or oyster shells, one may see the little twisting tubes of lime which the worm, called the serpula, makes. If the stone, with a live serpula on it, be put into sea water, the worm will thrust out its gills from the tube, like a small and beautiful fan.

Resembling worms in general shape, but very much higher in the scale of life, because of the organs which enable them to adapt their movements to a greater variety of changes in outward nature, are the animals classed together as **myriapods**, or ten thousand feet; not that they really have so many feet, but because they have very many. Their bodies are formed of a large number of rings, and from each ring springs a pair of feet.

The centipedes or hundred feet, one division of the myriapods, have a hard firm body. They are common enough, of a small size, in gardens here; but one must go to the West Indies to know what a centipede is. There they grow to twelve inches long; and their second pair of feet is pierced like a serpent's fang. Their bite is often a cause of death. They are wonderfully adapted for moving about, not by stretching themselves like a leech or worm, but by their large number of well formed limbs. A centipede moves, not like a boat with a hundred oars all taking stroke at once, but with a waving motion of the legs; each separate leg being in a different portion of its step at the same moment—one raised—another on the ground—and the rest in every phase between. Clip the animal in two as it moves, and the hind half goes on as if nothing had happened.

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* **Dorsibranchiates.** † **Tubicoles.**

The millipede, another of this class, rolls itself up into a close spiral when it is touched. One may see them often under stones, or in the wood of decayed trees.

Still higher than these, in the ranks of the articulates, are the animals called **crustaceans**, of which the crab and lobster are examples. As their name shows, they have a plated crust or limy shell over their bodies. This is secreted by the animal from its soft body, and serves it as a skin; but it is not like the shell of a mollusc—a house out of which it can creep when it pleases. They cast it each year; and this is needful, as they grow too big for it; and then, till a new one is formed, they lie soft and tender, a prey to all foes. They have five senses. Some live on land—more in water, salt or fresh. Their bodies are in three divisions—the head, the thorax, and the abdomen. All the organs of the senses are about their head. There are three kinds of them—the stalk-eyed,* the shelled insects,† and the curl-footed.‡

The stalk-eyed have their eyes placed at the end of stalks, not in hollows of the head like most other animals. Among them are lobsters, crabs, prawns, shrimps, and crayfish. They take great care of their young. They have five pairs of limbs. In the lobster the first three pairs end in pincers. All these animals have the strange power of replacing any of their claws, when they have been torn off. A sudden noise will even cause them to throw them off; and the firing of a ship's gun has been known to spoil a haul of lobsters in a fisherman's boat. The lobster swims with its fan-like tail, striking the water downwards, and thus going backwards; but then it has very long feelers which it lays along over its body, and thus feels its way so well, that it will dart backwards with the greatest nicety into a hole only large enough to admit it.

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* *Podophthalms.* † Entomostracans. ‡ Cirrhipeds.

The crab has two pairs of feelers which it can stow safely in grooves of its shell; it can draw its legs close under its body around the mouth—and thus, feelers packed away, and legs drawn up, the waves, in a storm, may toss it about like a piece of wood, and it will receive as little harm as the wood. There are land crabs in the West Indies which travel in millions between the mountains and the sea; and march in a straight line over houses, and through fields and gardens, never breaking their ranks. They destroy much fruit by the way, and the negroes gather and eat them. They breathe by gills, and have in their bodies a store of water, with which they keep their gills moist while they are on shore.

The shelled insects are all small creatures, the best known is the common water flea. The curled feet are very unlike the other crustaceans; and are commonly known by the name of barnacles. They cling by a tough stalk to stones or pieces of wood, and the bottoms of ships. At the end of the stalk is a jointed shell in which the animal lives; and catches its food by thrusting out its curled feathery claws or feelers. So it lives fixed like a plant, yet in youth it was a freely swimming animal, with eyes on foot-stalks, and six pairs of jointed legs. The abundant little conical shells, which cover rocks and stones at low water with a white shelly crust, and which are apt to cut the feet of bathers, contain also a small animal of this kind, which, when young, was a distinct crustacean in form. It is pleasant to watch them when the rising tide has just covered the stone on which the shells are fixed, thrusting out and whirling their curled feelers to make the water bring them food. Put a stone or a limpet covered with their shells into a glass of sea water, and their movements may easily be seen.

The animals of the spider class, called **arachnids**, are higher in the scale of life than the crustaceans. The higher kinds of them breathe by a kind of air sac or pouch, something like a lung—the lower by means of many little openings into air-tubes. They have mostly eight legs; and all of them have at least two eyes, many have eight, some twelve. According to their mode of breathing, they form two divisions called lung-breathing,* and air-tube breathing.† Among those that breathe by lungs are the spiders and the scorpions.

Every one knows the shape of a spider, its small head and breast, and large round body, with thin outspread legs. At the back part of the body are fine little teats, each pierced with hundreds of holes, out of which it sends a gummy substance which it twists with its hind legs, and which, as it dries in the air, forms the threads of its web. Everyone knows, too, how skilfully the web is made to catch flies, upon which the spider feeds. Some small spiders dart out their threads into the air, and then float along at the end of them, hanging upon nothing. These are the gossamers which often annoy us by coming on our faces in the summer evenings. The mason spider digs a house in the ground, forming underground galleries and passages which it makes cozy with a silken lining out of its own body; and shuts up with a door of clay or earth, hinged by its threads. The little black and white spider, called the hunting spider, forms no web, but hunts flies by creeping gently towards them, and springing suddenly upon them. The water spider, though breathing air, lives under water. To manage this it spins a ball of silk, and has some means of conveying bubbles of air to fill it. There it takes up its abode and watches for flies during the summer. In winter it closes up the ball, and sleeps inside of it during the whole of the cold season.

Scorpions fortunately are not so common as spiders. They live in warm climates. They have large claws shaped like those of a lobster; and a long knotted tail, in the last joint of which is a hooked, sharp, and poisonous sting. Out of doors they hide under stones; but they often get into houses, and nestle in soft places, such as beds. When alarmed they run with the tail curved over the back, ready to strike. They live upon insects; but men have good reason to dread their sting. No careful mother in tropical countries will lay baby down in its couch, without first seeing that the couch is clear of scorpions.

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* Pulmonars. † Tracheans.

Among the air-tube breathing arachnids may be mentioned the cheese mite; the little animal which causes the itch; and the small red spider which infests bees.

CHAPTER IV.

INSECTS.

INSECTS form the highest class of the articulates. They owe their name to the fact that they are, as it were, cut into three sections, head, thorax and abdomen; between each of which the body is extremely small. Insects, like all articulates, are formed of distinct rings; those of the head are so close together, that they can hardly be distinguished; the three rings of the thorax, from each of which comes a pair of legs, are also very close; but the abdomen is formed of nine or ten very distinct rings.

They are far more perfect in their organization than myriapods and spiders. They have six legs; a few, indeed, have no wings, but the rest have either two or four. Their bodies are covered with a horny substance called **chitine** by the chemists. This serves them as an outside skeleton, to which their muscles are attached. This skeleton, however, is flexible in most insects. The varieties of their form—their beauty, especially that of their wings—their immense numbers—the life they give to any scene, as they flit about over sea-beach, gardens, fields, and woods—and the great use of some of them, as well as the frightful damage which others cause, have made them always objects of earnest study to mankind. Indeed, the study of them forms a special branch of natural history, called entomology. Perhaps the most wonderful fact in the life of insects is the strange series of changes through which they pass, called metamorphoses. Only in the last stage, produced by these changes, do they produce their young. An insect is first an egg. It comes forth from the egg like a little worm; this is called its larva state. The name larva means a mask; and is given to this state because the skin of the worm hides or masks the real insect. In the larva state it eats greedily, much more in proportion to its size than an ox eats, and of course grows rapidly. Its food consists of the plants or refuse matter among which it is born from the egg. Caterpillars are the larvæ of butterflies and moths; grubs are the larvæ of beetles; and maggots, of flies.

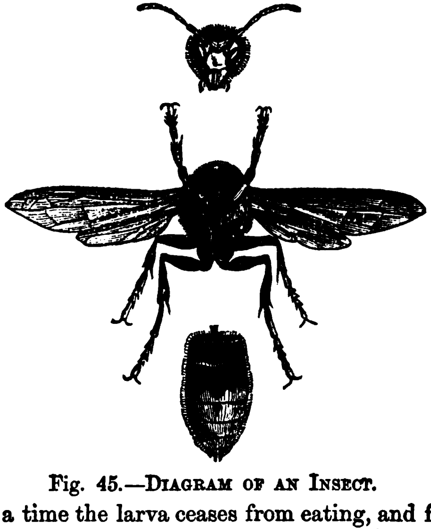

Fig. 45.—Diagram of an Insect.

After a time the larva ceases from eating, and falls into a quiet state, during which it is quite still, apparently dead; and lies wrapped in some kind of a horny case, or in a flossy, silky covering which it has spun for itself, and which is called a **cocoon**. This quiet state is called the **pupa** stage. The pupa of a moth or butterfly is called a chrysalis; and some larvæ change their skins several times before they enter the chrysalis state. When they are about to enter it they roll up the edges of a leaf on which they have been feeding, and gumming them together form a wrapper for themselves; or creep under the bark of a tree; or into the ground; or a chink of some old wall, and there hang themselves by a thread; or else lie still on the ground and spin their cocoon. At last, after a period of rest, there comes out of the skin of the pupa, the imago, or perfect insect.

The perfect insects are wonderfully marked by their possession of those peculiar powers of mind which we call instincts. In the providing for the wants of their young, the making of nests, and the like, they seem to do always the right thing at the right moment, and in what appears to be the best possible way; not by a slow process of reasoning, but at once. Many female insects never eat after they have attained the winged stage; some, like the butterfly, suck only the juices of flowers; but whether they themselves eat or not, they always lay their eggs on, or near, the very food which the young grubs require to eat. The butterfly which sucks flowers lays its eggs on leaves; the beetle, which does not itself eat roots, lays its eggs among earth in which roots are; and moths, which do not themselves eat flies, are always careful to put a dead fly into the holes in which they lay their eggs. Does the full grown insect remember what it ate itself when in the larva state, one might ask?

Another remarkable fact about insects is the number of eggs which some of them lay. The silk-worm moth lays about 100; the great goat moth about 1000; the wasp, 30,000; the queen bee, 40,000; and some female ants, 100,000. The eyes of insects, too, are strange. Our eyes are what are called simple eyes; but we have the advantage of being able to turn our two simple eyes in different directions. The eyes of insects are either simple or compound, some have both kinds. A compound eye is made up of a great number of fixed, six-sided eyes, the fronts of which are called facets. There are about 50 facets in each eye of the ant; 4000 in each of the eyes of a house-fly; 17,000 in those of a butterfly; and 25,000 in those of some beetles. These facets are separate eyes, containing all the parts which our eyes have—pupil, lens, iris, and nerve.

Insects have neither lungs nor gills; they breathe by means of air tubes, opening in holes on their sides. The fluid which nourishes their bodies does not circulate, but bathes all their organs, and seems to be absorbed by them. There are eight orders of the class of insects—the *wingless;*[*] the *two-winged;*[†] the *scaly-winged;*[‡] the *web-winged;*[§] the *nerve-winged;*[||] the *half-winged;*[¶] the *straight-winged;*[β] and the *sheath-winged.*[γ]

The **wingless** insects are mostly born from the egg in the shape they retain through life. The flea is an example of this order. Its young undergo a change; first there comes from the egg a tiny worm, which curls itself in dust, or among the hairs of animals, or on down. Those who shake clothes often easily keep clear of them. After a time the little worm spins some fine threads round its body, sleeps a day or two, and then comes out the active little animal that can jump 80 times its own length, by means of its strong hind legs.

There is a very small flea in the West Indies called the chigoe. It enters the skin of the feet through the best sewn boots, settles between the toe nails and the skin, and there produces a colony of young ones in a bag. Negroes are often seen without one or more of their toes. They have been eaten off by chigoes. With a little care and cleanliness this might easily have been prevented.

The **two-winged** insects shew an advance in perfection of organs beyond all the orders of animals below them; for they are fitted to move in the air. Still they are below birds in this respect, for their wings have not strength enough to resist the wind; they cannot therefore always choose the direction in which they will fly. In this order are all kinds of flies, midges, gnats, mosquitoes; and there is a very great number of species, all having the mouth formed for sucking food, as flies suck wet sugar or spilt milk. The mosquitoes suck blood from animals, and are the torment of people in warm climates.

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[*] Aptera. [†] Diptera. [‡] Lepidoptera. [§] Hymenoptera. [||] Neuroptera. [¶] Hemiptera. [β] Orthoptera. [γ] Coleoptera.

The **scale-winged** insects are the butterflies and moths, and are the most beautiful of their class. They feed by means of the long curled tube which projects in front of their head—pumping out the sweet juices from flowers. They have four large thin wings, covered with feathery scales, which look like fine dust, but are really scales that overlap in rows, and are fixed to the skin of the wing by a small root. On a square inch of the wing of a large butterfly, seventy rows have been counted, with ninety scales in each row, making 6300 altogether. The scale-winged order are arranged in three families—the *day*, the *twilight*, and the *night* families. In the first are the butterflies resplendent with beauty, such as the peacock butterfly. In the second are the hawk-moths, the largest of which is the death's head hawk-moth, so called because it has a mark like a skull on its thorax, and flying about in the grey twilight frightens silly folks. The night insects, or true moths, are well known. Who has not seen them dashing at the light? and what good housewife has not mourned over their destruction of her cloth or fur? However, it is to the cocoon of a moth that ladies owe their fine silk dresses.

The **web-winged** insects have four thin transparent wings, without any scales on them. The two front wings are the largest, and are joined to the two hind ones, so that the four seem only a single pair. In the abdomen of these insects is a tube which can be quickly thrust out, and serves some kinds for laying eggs. By means of it the web-winged insect called the ichneumon lays its eggs in the bodies of caterpillars. After the egg is hatched, the grub feeds on the caterpillar, then eats its way out of it—a winged ichneumon. In the battle of life the caterpillar has thus the worst of it, and dies that the ichneumon may live. Other web-winged insects use this tube as a sting. Such are bees, wasps, and ants—insects which live in societies and form combs of wax, or nests of a paper-like substance in which they carefully guard and feed their young.

Bees live in societies in which there are commonly about 2000 male insects or drones; only one female, called the queen bee; and from 20,000 to 30,000 neuters or working bees. These last are usually said to be of no sex, but are really female bees brought from the egg at an early stage of their growth. Sometimes there are two females in one hive, but when this happens they fight till the one kills the other; or else one flies off to seek a new home, with a number of drones and neuters following. This flight is called a swarm. The beaten queen alights at last on a branch of a tree; and her followers all settle on and around her, forming a mass of bees hanging from the branch like a large bunch of grapes. When the bees are wild, some of the neuters go off and seek out a new spot where they may found a society; and when it is found, all go there. But when the bees have come out of a hive that men keep, a new basket hive is at once got ready for them and held under the swarm, while they are struck off the branch into it with a board. It is then turned over, and they are shut up in it with only the little hole at the front to go in and out at. If the queen be shut up with the rest, they settle at once; if not, they fly out again, seek her, and alight on another branch, where they are caught again along with their queen.

The queen remains always in the hive, and the drones wait upon her; whereas the neuters or workers go out and roam among flowers to get honey and materials to build cells in the new hive. The pollen which sticks to their hairy legs, they collect between their thighs and carry home in little pellets; and the juices which they suck from the flowers, they convert into honey in their honey-bags. The pollen mixed with honey forms what is called bee-bread. From between the scales of the abdomen of a number called wax-workers, wax oozes out, and is used by the other workers to build the combs, which consist each of two rows of cells, set back to back. The exactness with which these cells, all six-sided, are made is most astonishing. The manner in which they fit to each other is very difficult to explain, for thousands of bees all begin at one time to form them. If each one did not begin at the exact spot required, when their work met, some of the cells would be out of place or not of the right shape. Yet this never happens. When the combs are finished they stand in rows in the hive; and between them there is only room for the bees to pass each other.

As the common cells are made, special cells of a larger area and different form are set apart for the eggs from which the young females, or queen bees, are to come. When they are all finished the queen flies out, and all the drones follow her up into the air, away out of the sight of men; and the working bees remain, awaiting their return, in a state of great excitement. Back they come in a short time, and about two days afterwards the queen begins to go from cell to cell, and to lay an egg in each; nor does she cease till she has laid about 40,000. During this a cruel work goes on. As soon as the queen begins to lay, the workers fall upon the drones and kill them, casting their dead bodies out of the hive.

The young bees come from the eggs in the form of little white maggots, three or four days after they have been laid. The workers feed them with honey, and after about five days the maggot changes into a pupa, lies still, and the workers close up the cell in which it lies with wax. When the pupa is seven days old, the perfect bee comes out—breaks through the waxen cover, and, if it be a working bee, begins at once to go out like the rest and gather honey and pollen. After the working bees the young drones come out, and they do nothing but live idly as their murdered fathers had done before them. Next come out the young females, and as soon as one begins to break out of the cell, the queen of the hive rushes at her, and would kill her, were it not that the workers usually keep her back and divide themselves into parties.

Some are for the young queen, others for the old one. When the young one at last gets out of her cell they fight, and either the one kills the other, as was said before, or the old queen flies off with her followers, forming a new swarm; and the young one reigns in her stead.

What is the first act of the new queen? To go round all the cells in which there are eggs or pupæ of other females or queens and kill the tenants with her sting. Sometimes, in spite of her precaution, a sister and rival is born; and then there follows a fight in which one must die or take flight. Sometimes both die of their wounds, and a time of confusion occurs in the hive. No more work is done; and no one goes out to seek honey or pollen till a new queen is found. Sometimes one is supplied by the keeper of the hives; but the bees can at times make one for themselves. If there be any cells left in which eggs of working bees remain, from which the larvæ have not yet come out, the workers make a number of queenly cells, take these eggs from the worker's cells, and put them into the new ones. Fed and cared for in these roomy cells, the larvæ from such eggs become queen bees, and differ in no respect, that men can perceive, from other queen bees. It is thus evident that working bees are females, and their only difference from the queens or mothers of the hive arises from their growth in narrow cells, and perhaps from being differently fed in the larva state.

The **nerve-winged** insects have fine transparent wings, like a network of thready nervures. They have no sting. Dragon-flies are among the most striking and lovely of this order. So far as the art of flying goes, they seem to be the most perfect of insects. They fly quicker than a swallow, and often escape from it by sheer speed. They can fly backwards, forwards, to the right, or to the left, without changing their position. The larva and pupa of the dragon-fly differ but little; the larva lives in ponds; is brown; and has six sprawling legs, which give it the appearance of a spider. Its mouth is furnished with a large fang, with which it catches smaller insects. When it is old enough it crawls out of the water, and fastens itself to a tree or herb till the sun dries its skin. This, after a while, cracks down the middle and out of it comes the perfect insect in full beauty, except that the wings are short; but they soon grow. To the nerve-winged order belong the dayflies or ephemeral insects. They live about four hours as perfect insects, have short feelers, and their front wings are much longer than their hind ones. At the end of the abdomen are two or three long feelers. To the same order belong the ant-lions; the strangest thing about them is the mode in which their grubs dig a hole in the sand, as a trap for ants. They lie in the bottom of this hole and wait till an ant, creeping carelessly by, falls in. If it fall only partly in, they can pelt it with grains of sand to bring it completely down; after which its juices are soon sucked out, and the dry body is thrust to a side. The perfect ant-lion is very like a dragon-fly.

The most noted order, however, of the nerve-winged insects is that of the termites, or white ants, as they are called; though they are not ants at all. These will eat into the hardest beam of wood, and leave a shell of it thinner than paper. Stanley, the discoverer of Dr. Livingstone, relates that when he examined certain stores, he found that the white ants had not only eaten up bodily the box in which the guns were packed, but they had also eaten the gunstocks. They hollow out thick trees; and build for themselves conical earthen houses, to which their numerous cells give a spongy appearance. These houses are ten or twelve feet in height; and the termites live in them, forming a society in which there are four distinct kinds—males, females, workers, and soldiers. They form long covered galleries to a distance of many yards from their high house or nest; and, in fact, seem to excel other insects, even bees, as much as Europeans excel Africans or Asiatics. The woodlouse, which we often see running about in old drawers, and among papers, is a kind of termite.

The **half-winged** insects justify their name by the fact that, in many kinds of them, the male only has wings. They owe it, however, to this, that in many kinds the upper wings are one-half hard and horny, the rest being thin and like a fine membrane; or else they are membranous, but tougher and larger than the lower wings. These insects have a horny beak, by means of which they can suck blood, or other juices. Bugs, plant-lice, and the cochineal insects, are the three most important kinds of the half-winged class. The common, rank-smelling bed bug differs from the other species by having neither the hard nor the membranous wings. Plant lice, the pests of our rose and apple trees, have become interesting of late in natural history, since it has been discovered that a female produces young ones that are neither male nor female, and these produce others, and so on for eleven or twelve generations, after which the young are again born male and female. The plant lice produce a kind of honey, for the sake of which they are said to be made prisoners by ants, and kept in ant nests, as men keep cows for their milk.

Cochineal insects are famous for the red dye or paint which they furnish. They live in Mexico, feed on a plant called nopal, are carefully gathered from the leaves, dipped in boiling water, and then dried in the sun. 70,000 of them weigh only one pound.

The **straight-winged** order, have tough upper or front wings which overlap, and the under or hind wings folded like a fan. The larva and pupa resemble the perfect insect, except that they have no wings. They are divided into two kinds—runners and leapers. The runners have legs nearly alike in length; the leapers have the hind ones longer and stronger than the others. Among the first are the earwigs, so named from a foolish notion that they creep into the ears of people. They have two curved pieces, like a pair of forceps, at the hinder end of the body. They are very destructive in gardens, as gardeners well know. The common cockroach also belongs to the running division; so, too, does the mantis or praying insect. This has a strange long shape, large jutting eyes, and the fore-legs covered with long spines. It sits on its hind legs watching for small insects, in an attitude like that of one praying with hands clasped. Its fore-legs are stretched out and held together; its body is perfectly motionless; only its cunning head turns from side to side, on the look out. The unfortunate insect which flies past is suddenly seized by the fore-legs which close on it, and squeeze it beneath their spines. These praying insects fight with each other as if they were fencing, making strokes and guards with their fore-paws as if they were swords. Sometimes one cuts the head of the other clean off, or divides the body in two. The winner then eats up his beaten foe. Some of this tribe are called walking leaves, from their resemblance to the dried leaves of a tree. It is interesting to think how useful this resemblance may be to them in the struggle for life. Their prey will come readily near them, being without fear of what seems only a leaf; and the enemies that might destroy them will often miss them, seeing, as they think, nothing but a leaf.

Among the leapers of the straight-winged order are locusts and crickets. The locusts live on vegetables, and overrun eastern and southern countries in immense hosts, eating up everything green. They leap rather than fly, and use their wings only for support in the air, not for motion through it. They are often driven into the sea by the wind; their bodies cover the waters for miles. When they are not drowned in this manner, they are generally starved in the lands which they themselves have rendered desolate; and their dead bodies corrupt the air, bringing pestilence in the rear of famine.

The crickets are the merry little creatures which run about the hearth in English kitchens, and being fond of heat, chirp as the fire blazes. Their chirp, however, is a sound caused by the rubbing of their thighs against the hard front wings. They are believed by some to bring luck to a house; the belief, at any rate, brings luck to themselves; and, probably, they repay the favour by eating the eggs and larvæ of more hurtful insects.

The **sheath-winged**, more commonly called beetles, are the most numerous of all the orders of insects. The first pair of their wings, which are called **elytra**, or sheaths, are hard, horny, and glossy, and form shields for the hind wings, which lie snugly folded under the shields, when the insect is at rest or walking. They have two large compound eyes. They have strong, sharp, horny mandibles or upper jaws, often of strange shape. Their lower jaws are not so strong; and from them come two pairs of feelers, called palpi; while from the sides of the head, near the eyes, come a long pair of jointed feelers, or antennæ. The whole covering of these insects is hard and shiny, except at the back part of the abdomen.

They undergo complete metamorphoses or change; the half-winged and the straight-winged classes do not. There are about 20,000 different species of beetles known.

Tiger beetles, ground beetles, and water beetles, are beasts of prey; that is, they hunt after and devour other kinds of insects. Burying beetles, when they find the carcase of a dog or a cat, make holes in it, and lay their eggs in them, so that when the larvæ come out they find their food all round them; but when the carcase is small like that of a mouse or a sparrow, they undermine it, till they have made a hole into which it sinks; they then lay their eggs in the flesh, cover it over, and leave it to time. They thus form a kind of scavengers who help to rid the earth of decaying animal matter. The common dung beetle renders the world a similar service.

Others of the beetle tribes, while they are in the larva state, devour earth and roots. The perfect cockchafer eats only leaves, but its larva works great destruction in pastures, by eating the roots. The beetles called scarabees have strange spiny horns on the head, or on the covering of the thorax. One of this kind was held sacred by the ancient Egyptians; it has the habit of wrapping up each of its eggs in a ball of dung, and rolling them with its hind feet to a hole in which it collects them all and leaves them. The stag beetle is marked by its large strong mandibles or upper jaws, which resemble stags' horns. It is said to grasp young ash or oak trees by them; then keeping them fixed, it flies round and round making a pivot of the tree, till its jaws cut through the bark; after which it feeds on the juices of the inner bark.

. The glow-worm is one of a tribe of beetles which shine at night with a brilliant phosphoric light. The use of this to it is unknown. The fire-flies of the tropics are of the same kind. Nothing can be more splendid than the sight of thousands of these flying in a dark evening in circles through the air, like thousands of disorderly revolving stars; and often the resident in hot climates, when he awakes during the night, sees numbers of them like creeping lights moving over the thin gauze curtains, which he has carefully closed all round him to keep off mosquitoes. Negroes light themselves on their way at night by tying a number of them in a small gauze bag, and fastening this bag to their toes. The light of the British glow-worm is a trifle compared to that of the fire-fly.

Thus insects, covered with horny shells which defy the attacks of foes, or gifted with stings which repel them—insects fitted to live under, or upon, the earth—on decayed or on growing plants—on living or dead animals—in the water or in the air—to suck nectar from flowers or to fatten on dung,—are wondrously adapted to draw advantage from all the products of nature, and to render their races successful in the struggle for life.

CHAPTER V.

FISHES AND REPTILES.

So far we have learnt of the great division of invertebrates; we now come to that of the vertebrated or backboned animals, the division which is on the whole the most perfectly organised. We have seen something of the arrangement of organs in the most perfectly formed of them—man, and how that arrangement fits him for his surroundings in nature. The rest resemble him more or less. The skeleton of them all is within the body; their limbs are four in number, whether they be legs and arms, wings and feet, or fins. Their limbs are framed of bones joined to the back-bone and to each other. These are surrounded with muscles or fleshy parts, covered with skin. They breathe either by gills, as fishes do; or by lungs, as those do that live on land. Lungs are internal organs in the form of a sac or bag filled with branching air-tubes and vessels. Gills are external organs, fan-shaped, or comb-shaped, or feathery; the blood-vessels in which float, as it were, in water; and draw from it the air required to purify the blood that is in them. The mouth of vertebrates is always in front of the head; and in it is a tongue, an organ found in none of the invertebrates. There are four classes of them, *Fishes*, *Reptiles*, *Birds*, and *Mammals*.

FISHES.—The organs of fishes are all adapted for life in water. Their senses are dull; their ears have no outer hole, and can be of little service to them for hearing; the vapours which, floating in the air, cause the sense of smell in land animals, can produce little effect on the nostrils of animals living in water; their eyes are fixed, and have no tear-glands, and objects must be very near before they can see them; while their bodies, covered with scales, must be little sensible to touch. They never chew their food, and have, therefore, probably but little sense of taste; and their tongues are often bony, or covered with a kind of toothed plates. Some of them have strong teeth, it is true, but only to catch and hold their prey, which they swallow whole. Their shape is simple; they have no neck; no large or long limbs project from their body, which is roundish, boat-shaped, and tapers to the tail. This fits them well for moving through the water, and most of them have an air-bladder in the upper part of the belly, by pressing or slackening which they can rise or sink in the water. Their gills, placed on each side of the neck, are made up of rows of thin fleshy plates, fixed on bony arches. The water which they take in at the mouth passes backwards among these plates, bathes all their surface, and parts with oxygen from the air contained in it, to the blood-vessels winding over the plates.

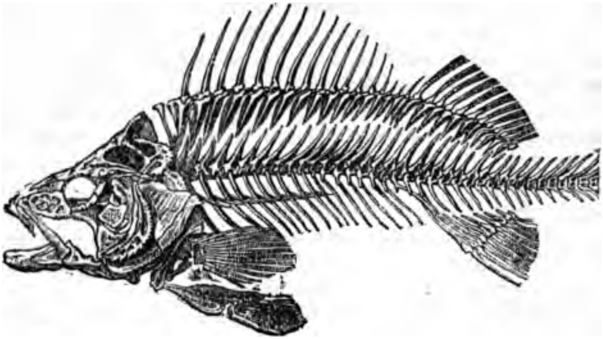

Fig. 46.—Skeleton of a Perch.

For limbs they have fins—one pair on the breast called **pectoral**, and another pair on the belly called **ventral** fins. Sometimes they are on the throat instead of on the belly. One fin, in two divisions, called the **caudal** fin, forms the tail; those on the back are called **dorsal** fins; and a small one on the belly near the tail is called the **anal** fin. Fishes differ from other vertebrates, in having bones not joined to the back-bone in any way, which serve to support the single fins on the back and belly, and which are thickest at the skin, tapering inwards. Without true limbs, they can catch things only by the mouth. Some live on vegetable substances; but most of them on other fishes, and on molluscs. The strong ones eat the weak; a single pike has been known to devour one hundred roaches in a day. They produce their young from eggs; and the number which one female will produce is very great. The roe of a herring or a cod is made up of an immense number of eggs, as many as 32,000 are laid by a herring in a year.

They are dumb stupid animals. The most noticeable of their instincts is that of migration, or changing from one place to another. Salmon swim up rivers at one time of the year, and come down again to the sea. Herring, mackerel, and cod leave the neighbourhood of the shores at certain seasons and return at others. They take these voyages to seek places which fit their young; and in which, therefore, they lay their eggs. They seem to have little or no affection, and for the most part leave their young to shift for themselves. They are cold-blooded animals, and are seldom warmer than the water in which they live. Some fishes prepare a place with their fins to lay their eggs in, and pile up heaps of sand to prevent them from being washed away by currents. Only one, the fresh-water stickle-back, builds a nest of water-weeds, in which it lays its eggs; and both male and female watch over the young ones for a while.

Fishes are divided into two great divisions—*cartilaginous* or gristly fishes, with soft bones; and *osseous* or bony fishes. The first have no ribs, and are inferior to the second in organization.

The **Cartilaginous** fishes are arranged in three orders,—the **round-mouthed,*** the **sharks,†** and the **sturgeons.‡**

The chief character of the **round-mouths** is the round form of the mouth; adapted better to suck than to eat. The fresh water and the sea lamprey resemble eels, and are much prized by those who like good eating; two other kinds of them, the myxene or hag, and the amphioxus or lancelet, are soft and jelly-like, of the nature of molluscs.

The order of **sharks** contains the ugliest and greediest of fishes, such as the sharks proper, which are the terror of seamen; the skates or rays, noticeable for their diamond shape, with eyes on the upper surface, mouth, nostrils, and gills opening on the lower; and the torpedo, or electric ray, which gives an electric shock, and thus, probably, kills the smaller animals on which it feeds.

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* *Cyclostomes.* † Selachians. ‡ Sturonians.

The **sturgeon** order have bodies covered with bony plates in rows, and sharp spines projecting from them. The upper half of the tail-fin is longer than the lower half. Their flesh has the taste of veal, and their roe is made into caviare, their air-bladders into isinglass. They are sometimes caught eight or nine feet in length.

The **Osseous** fishes are divided into two orders—the *soft-finned* * and the *sharp-finned.*† Almost all the fresh water fishes which are prized for eating are of the first order. Such are the river fish—trout, gudgeons, carp, tench, and jacks; such, too, are the sea fish—herrings, sardines, anchovies, whitings, cod, turbot, plaice, and soles. Such, too, are the salmon and the shad, which are half sea and half river fish. The eel kind forms a division of the soft-finned order, called the **apodal**, or footless. Eels, too, leave the sea for rivers, in order to lay their eggs, or to spawn, as it is called. Sometimes eels creep out of the water and crawl among wet grass. One of the most remarkable of the soft-fins is the flying fish, which is not unlike a herring with very large fins. They live in tropical seas, and leap so far, and keep themselves, by means of their outstretched fins, so long out of the water, that they seem to fly. They do so to escape the pursuit of larger fish; and are often caught in the air, by large birds, like the albatross and frigate bird. They seem sometimes to rise and dart at a light; at any rate they are often found dead on the deck of a ship in the morning, having dashed themselves against the binnacle, attracted probably by the light in it during the night.

The sharp-finned fishes have not such a variety of orders as the soft-finned. Among the sea fish of this division are the tunny and the mackerel; among the river fish, the perch.

REPTILES.—The word reptile means a creeping animal; but many of those to which the name is applied leap, and even run smartly. They are divided into four orders —*frogs,*‡ *serpents,*§ *lizards,*‖ and *tortoises.*¶

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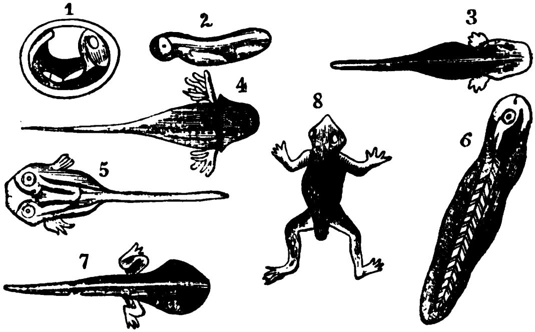
* Malacopterygians. † Acanthopterygians. ‡ Batrachians.
§ Ophidians. ‖ Saurians. ¶ Chelonians.

The **frog-like animals** have for their best known examples the frog and the toad. The young of frogs and toads, like those of fishes, are produced from eggs; but when a young fish leaves the egg, it is of the same shape as an old one; whereas the little animal which comes from the egg of a frog is quite different from its parent, and is what is called commonly a tadpole. Thousands of them may be seen in spring in every pond or ditch—little black wriggling masses, with a long tail and feathery gills. They scuttle about in stagnant waters, feeding on bits of decayed plants, till their gills gradually disappear; hind legs begin to form; soon afterwards fore ones appear; the tail vanishes; the body becomes dumpy, and the fish has grown into a reptile, with a large head, bright staring eyes, and four legs. It breathes now by means of lungs, and catches living prey, such as worms and insects. This is an example of what is called development in natural history; an animal of one kind apparently changing into another and a higher kind. There is another step of progress in the scale of animals to be noticed in frogs. Neither fish nor any of the animals in divisions lower than fish have a voice; but the frog, *having* ceased to be a fish, and become a reptile, can



1, Egg; 2, 3, 4, 5, tadpole with gills; 6, gills disappearing; 7, hind legs appearing; 8, reptile formed.

Fig. 47.—Changes of Toad.

croak. It has a true voice, different from the chirp of the cricket caused by the rubbing of legs and wings—a voice that is certainly not very pleasant to hear, but yet one that is caused by the throat and windpipe.

The frog and the toad are different kinds of the same division; but they are much alike in their mode of life. Their young undergo the same series of changes; they both eat worms, snails, and caterpillars; they have no ribs; and, therefore, though they breathe the air, they rather swallow it than inspire it. They are not poisonous, as ignorant people believe; and, in fact, the frog, if one could get over prejudice, is a pretty little animal. The toad is a slower and more ungainly animal than the frog; it crawls rather than leaps; and has a juice on its skin which is apt to cause eruptions on the hands of those who handle it. The preventive of this is not to handle it; and we may be sure that it can neither spit poison, nor give a poisonous bite. It has a beautiful bright eye, which the poet compares to a precious jewel.

There is a tree frog found in North America which has a set of organs fitting it to catch insects upon trees, and to catch young fishes and molluscs in the water. In South America there is a still more strange animal, called the pipa or Surinam toad. After the eggs are laid, the male sticks them one by one on the back of the female. She goes into the water, and the eggs sink into her skin, as small stones would sink into pitch. They are hatched in the holes they make; and the tadpoles live quietly in these holes on their mother's back till they become reptiles; the mother then rubs off the old skin and returns to land.

Among the frog-like animals are included salamanders or water newts, which somewhat resemble crocodiles in shape. The salamander of the continent, black with yellow spots, is larger than a frog. It is thought to be poisonous, and that fire cannot burn it; but both beliefs are absurd.

There are some of the frog-like animals which have both gills and lungs during the whole of their lives;

being thus both fishes and reptiles at once. One called the axolotl, found in the lake near the city of Mexico, and another, with no eyes, found in caves in Austria, are not unlike tadpoles of the water newt. One called the siren, is liker an eel than a frog; it breathes both by gills and by lungs, and has fins. These animals are those to which the name amphibious should be applied, for they really have two modes of life—life on land and life in water. They are a subject of great curiosity to those naturalists who teach that the higher animals have grown from the lower ones by a series of slow changes called development; and who seek to show that thus fishes have developed into reptiles. "Here," they say, "are animals which are both of them at once; and the reptile frog is, in youth, the fish tadpole."

The **serpents** resemble a lamprey in shape, but are very different in the form of the mouth. The jaws of serpents are so loosely joined, and the skin around them is so elastic, that they can gape wide enough to swallow prey which is out of all proportion larger than their heads; they have sharp, backward curving teeth. Most of them have but one large lung. Their bodies are very long, with very many ribs, upon which they walk in the same style as the centipede with its feet. But the serpent's feet, as we may call its ribs, are inside of the skin. The bite of some serpents is poisonous, of others not. Those whose bite is not poisonous have four rows of teeth in the upper jaw, two large and two small; in the lower jaw, two large rows. Those whose bite is poisonous have no small teeth in the upper jaw; but, instead, they have a long curved, tube-like fang, which lies back on the jaw, hidden usually by the skin, but is erect when the animal wishes to bite. Through the tube of the fang comes poison from a bag in the gum. It passes into the wound which the fang makes, and stuns the victim. At times men die of such a bite, but there is no need to believe all the terrible stories told about the bite of serpents. There are dangerous serpents of this kind in Asia, Africa, *and America;* the viper is the only one of the kind in

Europe. We may find it on heaths, and may know it by the diamond-shaped black spots along the back. The common snake is not dangerous. All, whether dangerous or not, cast their skins yearly.

The boa constrictor is a name commonly given to all large serpents. It belongs properly to those of America. The python is the name given to those of the Old World, of the same kind. They are not poisonous. They grow as long as thirty, or even fifty feet; and catch their prey—deer, oxen, or man—by darting on it from trees to which they cling by winding the tail round the branches or trunk. They twine the fore part of their long bodies like a cord round their victims, and then tightening their folds, they squeeze it to death, and mash up all its bones by their pressure. They then cover it all over with saliva, and swallow it in one mass—jaws and throat expanding to let it pass into the stomach. Luckily, they are not hungry above once in three months, and can even fast six. Clearly they have no very acute sense of taste. When gorged with food they lie quiet, and may easily be killed.

The rattlesnake of North America gets its name from the bones at its tail, which are like a number of thimbles, one inside the other, and which rattle when it shakes them. This rattling warns those who are near it, and though it will bite when attacked or trodden upon, it would rather get away from a man than begin an attack upon him. The bite often causes death, oftener only an illness. They, and other snakes, are said to fascinate birds, that is, to deprive them of the power of flying away after they have come near. The rattlesnake shelters its young ones in its mouth when danger threatens. These are not thicker than a goose-quill at first.

The **lizards**, or saurians, somewhat resemble serpents in the head and in the long tail, but their organs are more perfect in respect of motion; for they have mostly four feet, some have only two. Their bodies are covered either with scales, or with a rough grained skin. The name lizard, given to the whole order, belongs properly only to those animals of it which are small, and live on land. The larger reptiles of the same order are amphibious, but pass most of their lives in the water. The lizards proper are lively, pretty little animals living in warm European countries, and abounding in the tropics. The green lizard of the south of Europe is the prettiest of the tribe—about a foot long, of a brilliant golden green, varied by rows of black dots. Lizards climb up walls easily, are not afraid of man, and run about the houses in tropical climates. They have an acute sense of hearing; are very fond of music, and will come quite close to any one singing or playing well, scampering off when harsh sounds are made. They have a kind of dewlap, or loose skin under the throat, which they inflate and spread out very comically.. Some lizards can almost fly; their ribs project outwards, and are covered with a thin skin, which, when stretched, acts like the parachute of a balloon, and prevents their falling as they leap long distances from tree to tree. One lizard of the West Indies, called the iguana, is much prized for its flesh. But, perhaps, the most remarkable of all lizards is the chameleon, common in the warm countries of the Old World. It is usually grey, but is of different colours at different times; perhaps because it can inflate its lungs and swell itself out till its skin becomes half transparent; the different shades may occur during different thicknesses of the skin. The chameleon lies for hours under leaves, watching till insects come within reach of its slender sticky tongue, which it darts out upon them with the speed of lightning.

The huge lizards of the waters are not such agreeable animals as their small land kindred. They have coarse skins, slanting fiery eyes, and rows of serried teeth. They are clumsy creatures on land, easily avoided or killed; but they make the large rivers of warm countries dangerous bathing places. In African rivers live crocodiles; in those of Asia, gavials; in those of America, caymans. They swim about at a moderate depth, and seize swimmers, dragging them under water and drowning them. Their windpipes are so formed that they can themselves breathe while they hold their prey in their mouths and drown it. They do not eat it at once, but let it lie till it has decayed a little—like sportsmen who eat game. They have thus an organ of taste, of a kind. They are cunning enough to prevent currents carrying away their prey, by piling stones over it, till nature has thus cooked it for them.

Tortoises are reptiles differing from the others in being shut up in a hard scaly box, from which they can only push out the head and the four feet. The upper part, or lid, so to speak, of this box is called the **carapace.** It is formed by the union of all the vertebræ into one piece, and by the flattening of the ribs, so that they touch each other at the edges. The united ribs enlarge at their ends and form a kind of border to the carapace. The vertebræ of the neck and tail are free. The bottom of the box is formed of the expanded breast-bone. It is called the **plastron.** The outside of the skeleton is covered with a series of horny plates of regular and beautiful forms and marking, jointed closely, or overlapping. These plates are called tortoise-shell, and are used to make combs, knife-handles, and many articles of ornament; but they are only plates of hardened skin, and form neither the shell nor the inner skeleton of the animal. The muscles of the fore legs and neck are inside of the carapace; so are the shoulder bones, and the bones and muscles of the thighs.

Tortoises have been fancifully described as animals whose bones have been drawn from the inside to the outside of their flesh. Their jaws have no teeth, but are hard and horny, forming a beak like that of a bird. The head, neck, and tail are covered with a tough skin, on which are plates of shell. They are divided into three kinds—sea-tortoises or turtles; fresh water tortoises; and land tortoises.

The sea-tortoises or turtles are the largest. They come on shore once a year to lay their eggs; they bury these in the sand, and leave them for the heat of the sun to hatch. Their feet form paddles for swimming. The green turtle is well known because of the rich food which it yields. Its eggs are delicious; different parts of its flesh taste like fowl, or veal, or steaks, and its fat forms the famous turtle soup. The hawks-bill turtle cannot be eaten, but its shell is valuable. Fresh water tortoises are not so large as turtles. They live in warm countries, in marshes, and large rivers. The small land tortoises, such as the common Greek one, often sold in the streets, are interesting. They live above a hundred years; but they are torpid more that half of that time, sleeping during the whole of winter, and during all the dark hours and dull weather of summer.

CHAPTER VI.

BIRDS.

BIRDS, like insects, are adapted to live much of their time in the air. Like them, too, and like reptiles, they produce their young from eggs; but otherwise they are very differently organised. They are provided with wings and feathers; they have warm blood; and, like man, have a double circulation—one from the heart to the lungs and back again—another from the heart through the body and back again. Their lungs are large; their bones are light; and their whole frame is hollowed out, as it were, so that the body of a bird is filled with air, as a sponge may be filled with water. Their weight is thus very little in proportion to their size. They have neither lips nor teeth, but a beak formed of two projecting mandibles or jaws. In some the beak is like a wedge-shaped chisel for cutting wood; in others it becomes a probe for boring into wood, or a spear for fishing, or a pair of pincers for tearing flesh, or a sieve for sifting mud. Their feathers form a light warm covering, in some parts deliciously soft, like the down of the eider duck; in other parts strongly fixed on to a quill or tube, like the vanes of a wind-mill. The strong feathers of the wings are, as it were, oars to help them in moving through the air. The longest of these, at the outer edge of the wing, are called **primary** feathers; those nearer the body are called **secondary.** The feathers of the tail act like a helm, and the shorter feathers that overlap these are called **tail coverts.** Sometimes the tail coverts project a long way beyond the tail, like those of the peacock. Once or twice a year birds **moult,** or change their feathers.

The wings are fore limbs, or, as it were, hands and arms adapted to fly. The hind limbs or legs of birds are fitted for climbing, perching, swimming, walking; and their forms are as varied as their uses. The thigh is hidden within the body; the drumstick, as it is called, is not the thigh, but the leg; while the long thin shank, usually called the leg, is really the foot, of which what is called the foot is only the toes. A bird, therefore, walks on its toes. Commonly, birds have four toes, three in front and one behind; some, like swallows, have all four in front; others, like parrots, have two before and two behind. Running birds have three; or only two, like the ostrich.

The most remarkable part of the skeleton of a bird is the breast-bone, which is large and broad, shaped like the keel of a boat; and, indeed, the whole form of a bird is like that of a boat, and is well fitted to cut through the air. The strong muscles, needful for the down stroke of the wing, are fixed to the breast-bone; and the shoulders are kept apart by the well-known fork bone, or merry thought, which is the two collar bones joined together.

Among birds, besides their wondrous adaptation for flying, and thus securing their individual safety, as well as their food from a wide area of action, should be noticed the means of preserving the race which arises from what may be called their family feeling. Everybody knows how skilfully they build their nests, how patiently they sit upon the eggs, how carefully they feed and rear their young, never deserting them till they can take care of themselves. The cuckoo is the only exception to this; it lays its eggs in the nests of other birds, and leaves them like foundlings, to the care of strangers. Some birds pair for a year; others, like swans, remain with each other for life. The colour of the plumage, or feathers, of birds varies with the season and the sex; and many birds change the countries in which they live as the seasons change. These are called birds of passage.

Their habits, and the places which they frequent, are easily judged of by the form of their limbs; and the kind of food which they eat, by that of their beaks. According to these, birds have been divided into seven orders —*swimmers,*[*] or web-toed; *stiltwalkers,*[†] or waders; *runners;*[‡] *scrapers;*[§] *perchers;*[||] *climbers;*[¶] and *birds of prey.*[β]

The **swimmers**, or web-toed birds, which waddle so as they walk upon land, are graceful and easy in their movements through the water. Their feathers—thick, soft, and close—glisten with an oily secretion which secures them against injury by water. Their food is fish, molluscs, and other substances found in water. Their flesh has an oily taste. Their necks are long, so that they can find their food at some depth in the water, while they swim on the surface. Penguins, which are the lowest of the order, have only stumps of wings, but are strong swimmers. Their feet and toes are so placed that the bird is erect when standing. They leap rather than walk; and millions of them are to be seen standing in rows, like soldiers, along the Antartic shores. There are other web-toed birds which have very strong wings, and fly about fishing all day, often thousands of miles from any shore. Such are the little petrel; the large frigate bird; and the albatross. Pelicans and cormorants have enormous beaks, with a pouch hanging from the lower mandible, in which they keep the fish they catch till it is convenient to eat them. Cormorants are trained in China to go out and catch fish, which they bring back to their masters, getting a share of the fish as their reward. The duck, the goose, and the swan, have been domesticated; that is, brought in to live among men. There are many species of ducks, both wild and tame. The eider duck, which breeds in cold regions, furnishes the well-known eider down. The goose and the swan have both been wronged in common report. The first is not a stupid bird; and the other never sings, living or dying. There are black swans in Australia. The long-legged red flamingo, and the common sea-gull belong to this order.

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[*] Natatores. [†] Grallatores. [‡] Cursores. [§] Rasores. [||] Scansores. [¶] Insessores. [β] Rapaces.

The order called **stilt-walkers**, or waders, is marked by long legs. To it belong the heron, the crane, the stork, and the ibis. The heron is a lonely bird, very long legged, and long and sharp billed. It has large powerful wings; haunts marshes, lakes, and shallow shores for fish; and in old times gentlemen and ladies found sport in chasing them with falcons. The crane feeds on the worms and insects of inland marshy meadows. Some of the African cranes are very beautifully feathered. There are two kinds of storks in Europe, a white and a black. The white stork lives on good terms with mankind. It may be seen stalking quite fearlessly about the fish markets of Dutch towns, or feeding its young in a large open nest on the chimneys and steeples. It is a bird of passage, and after having reared one brood among the crowded towns and villages of Switzerland and Holland, it flies off to the marshes of South Eastern Europe, and rears another there. It rewards the care of man by destroying snakes and frogs; and many interesting stories are told of its devotion to its young.

The ibis was a sacred bird to the ancient Egyptians. Its colour is a bright scarlet. It migrates yearly from Egypt to Central Africa. Among the smaller birds of this order are the snipe, woodcock, curlew, plover, the lapwing, or peewit; the corncrake, or landrail; and the coot, or moorhen.

The **runners** have short wings, quite useless for flying; but their legs are long, featherless, and very strong.

The best known birds of this order are the ostrich, the cassowary, and the emu.

The ostrich lives in the sandy deserts of Africa and Arabia, and is the largest of living birds. It is two toed, and, like the camel, has hard bare knobs on those parts of its breast and body upon which it presses when it lies down. It is hence often spoken of as the camel bird, and its digestive organs are in many respects like those of the camel. It eats grain and grass, and swallows pebbles, and even pieces of iron to help it to digest, by grinding its vegetable food for it. It can run faster than a race-horse, and is, therefore, not easily caught. It kicks very hard when brought to bay. It piles up a heap of sand for a nest, and strides across the heap with its feet on the ground when it is sitting upon its eggs. It seems to have a peculiar instinct by which it knows what eggs will hatch; for the birds are said, before beginning to sit, to examine them all with care, and to throw away the useless ones. Its feathers have the fatal gift of beauty; for these it is hunted. The ostrich of South America is hunted also for its flesh.

The cassowary of the Molucca Islands and New Guinea has a kind of horny helmet on its head; a body covered with long hair-like feathers; and scarcely the stump of a wing. The Emu, which is strictly Australian, has no helmet; but, in other respects, it is very like the cassowary.

There are several kinds of stump-winged or wingless birds, which have become extinct within the memory of man—exterminated by him. To be without wings, is to be ill prepared in the struggle for life against such an enemy as man.

The **scrapers** form the class of birds which yields the most food for mankind; and, perhaps luckily for him, possess no great powers of flight. They are known under the common name of poultry; and if we except the pigeons, none of them can fly much farther than from the ground to a roosting place. They are sometimes named *Gallinæ* from the Latin word for a hen.* The cock and the hen are found wild in Further India, which seems to be their original home. The food of the scrapers is grain and seeds; to get these they are always scraping at the ground. The most of them are polygamous; that is, one male lives with many females. In this respect, too, the pigeon is an exception, for the pairs of pigeons usually remain faithful to each other through life. In general the males are splendidly feathered, and strut with a stately air before the females. The number of kinds of scrapers is very great; the most important are the common fowl, pigeons, pheasants, grouse, partridges, quails, turkeys, and Guinea fowls. Turkeys come from America, not from Turkey; the wild ones of the United States are very large.

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* Gallina.

Pigeons are found all over the world; and their tender cooing and gentle soft eye, make them everywhere the emblems of peace and love. The varieties of them are almost countless, and they are all said to be sprung from the wild kind called the rock pigeon. The wild pigeon of America migrates from place to place in search of food, and in such hosts that they darken the air. One traveller estimates a flock which he saw to have numbered at least 2230 millions. The strange and unerring instinct by which some kinds seek their home, is one that men have found useful. They carry the bird to a distance from its home; then—tying letters to it—set it free. It flies home at once, surely and swiftly. In this way, pigeons which had been taken to Paris, when the people were preparing for a siege, carried out news daily from the blockaded city. It is said that when a pigeon is let go, it rises up into the air in a spiral course, through many different currents of air, till it gets into the one most favourable for its course homeward; and then flies literally on the wings of the wind to its own cot, where the letters it carries are received.

The **perchers**, or passerines, as they are called, that is, sparrow-like birds, are very difficult to describe as a whole, there are so many kinds of them. They have short slender legs, three toes behind and one before, and the two outside toes on each foot joined by a very short web. Their slender toes are easily bent, and have long pointed and curved claws. The males are larger than the females, and in some of them the voice as well as the plumage is wondrously fine. There are four distinct groups of them, the *conical beaks,*[*] the *toothed beaks,*[†] the *slender beaks,*[‡] and the *cleft beaks.*[§]

Among the **conical-beaked** perchers are the sparrow, the lark, the goldfinch, the canary, the cross-bill, the crow, the magpie, the jay, and the bird of paradise. This last is, perhaps, the most beautiful of all birds; it is found only among the islands of the Eastern Archipelago.

Among the **toothed beaks,** which have the upper mandible of their bill notched at its lower edge near the tip, and which all feed upon insects, are the thrush, fieldfare, blackbird, wagtail, robin, hedge-sparrow, stonechat, and the nightingale—the sweetest of singers.

Among the **slender beaks,** which live on insects or the sweets of flowers, are the nut hatch, the humming birds, and the lyre birds of Australia. The humming birds inhabit South America and the West Indies; are most brilliantly coloured, and exceedingly small. Some of them weigh only about the twentieth part of an ounce. They have long cleft tongues which they dart into tropical flowers, either to drag out small insects, or suck the juices of the flowers.

Among the **cleft beaks,** birds which catch their food on the wing, fly very swiftly, and open their mouths very wide, are swallows and martins; and the goat-suckers which hunt their prey by night. Kingfishers and bee-eaters are also placed in this division; but their bills are longer and stronger than those of martins or swallows. The kingfishers dive into water and catch fish; the others, as their name implies, live upon bees and wasps.

The order of **climbers** is much better marked than that of the sparrow-like birds. They have two toes behind and two before, by means of which arrangement they can grasp branches easily. They all walk badly, and do not fly well. The chief families of them are the **cuckoos, woodpeckers, parrots,** and **toucans.** The cuckoos are birds of passage—arriving here early in spring, when they make the woods resound with their strange and pleasant cry. They build no nest, and lay their eggs in the nests of other birds; one in one nest, another in another; and the eggs, it is said, differ in colour, each being of the same colour as those of the bird in whose nest it is laid. The young cuckoos are fed by this bird, which even neglects its own young for it.

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[*] Conirostres. [†] Dentirostres. [‡] Tenuirostres.
[§] Fissirostres.

The woodpeckers feed upon insects which they peck out from the bark or wood of trees. Their tongues are so formed that they can be stretched out very far and very quickly; and are tipped with hard horny barbs, upon which the insects are caught. Parrots are the models of climbing birds, with their strong hooked upper mandible and their finger-like claws. They live in tropical countries; and there are many kinds of them—cockatoos and macaws in America; perroquets or parakeets in Australia. Some kinds can be taught to repeat words very fairly; there are even wild kinds, which, when they have built their nests near a hut, learn to call out the names of the people who live in it. But many false stories are told about the speaking of parrots. Toucans are birds with enormous toothed bills.

Birds of Prey are fitted above all other kinds of birds for success in the struggle for life. They feed upon flesh; many on that of animals which they hunt and kill; others on carrion, or the flesh of dead animals. They live in single pairs. The males are not so strong or large as the females. Their beaks are strong; the upper mandible is hooked at the tip. Their wings are very large. They are arranged in two great sections: *nocturnal* and *diurnal;* that is, those that hunt by night, and those that hunt by day. The only family of night hunters is that of **Owls.** They have large round eyes in front of the head, and a short curved beak; and have a look of wisdom about them, which made the ancient Athenians count them the favourite birds of their goddess Minerva. Their chief exercise of wisdom consists in catching small birds asleep, hunting rats and mice; and, when they can get no better, insects and frogs. They have a strange melancholy cry.

The diurnal birds of prey are the boldest and most active of birds, well fitted for flight and fight. They are usually arranged in two grand sections—the **Vultures** and the **Falcons.**

The vultures are on the whole disgusting animals; they are large, and their heads and necks are bare of feathers, or only covered with down. They feed on carrion, and are thus of great use in hot climates. Their usefulness, however, never leads to their being regarded with aught but horror. Only when they cannot get dead flesh will they hunt; and then they mount high in the air, and wheel round in wide circles, descrying lambs and kids from afar in spots favourable for their purpose. Then they swoop down upon their prey, carry it off, and let it fall into some deep abyss, where it soon dies, and by nature's cooking in a hot climate, soon becomes ready for the palate of the vulture. The bearded vulture of Switzerland is the largest European bird. The condor of the Andes is still larger, being fourteen feet from tip to tip of the outstretched wings.

The falcon family are of much finer shape, and braver than the vultures. The chief kinds of them are falcons, hawks, and eagles. The eagle is justly called the king of birds. He sees farther, and can fly higher and longer than any other. He is the favourite emblem of poets for strength, and speed, and sharpness of sight. Men catch vultures when they have overgorged themselves, and cannot rise to fly; they can only get young eagles alive by climbing up the face of rocks to the eyry or nest. Man may compel the little falcon, or the hawk, to serve him; the eagle has never been tamed.

CHAPTER VII.

MAMMALS.—I.

THE most highly organised group of vertebrated animals, and therefore of all animals whatever, is the class of mammals. They are on this account the best fitted to derive pleasure from the materials of the world around them, or to avoid the dangers with which these materials, or circumstances, threaten them. Their name bespeaks the one fact, common to them all, that the females nourish their young by means of special organs, called *mammæ*, or teats. They all, like mankind, breathe by lungs; and their young are born, not from eggs, but alive. Their jaws are furnished, for the most part, with teeth; and their limbs are fashioned in almost endless variety. On this variety depends their admirable fitness for the struggle of life; and on some of these variations depend the different modes which naturalists have adopted of arranging them in different orders. The limbs end either in hands or feet; some fly; some swim. Their teeth vary with their food; some can eat both plants and flesh; others only flesh; others only plants. The sense of touch varies in them according to the number of their limbs, and their division into hands and feet, fingers and toes; and to the ease with which these can be moved. The limbs of some end in hands only; those of others, in feet only; others, again, like man, have both hands and feet. The brain and nervous system is the special organ, or set of organs, in which they excel all other divisions of animals, both in quantity and quality; it may be said that by their mental powers—whether those of instinct, or those of reason--they form the excellence of creation. They are generally divided into three great sections: first, swimming animals* with neither hoofs nor claws; second, those that have hoofs† at the end of their limbs; and third, those that have claws‡ or nails.

* Cetacea. † Ungulates. ‡ Unguiculates.

The **Cetacea**, or whale-like animals, as their name means, have neither hoofs, claws, nor hind limbs, and are hence sometimes called **mutilates**. The most important kinds of them, such as the Greenland and Spermaceti whales, narwhals, dolphins, and porpoises are frequently spoken of as fishes. But though they live in the sea, they are like other mammals in all important respects. They breathe the air, and are therefore compelled to come to the surface of the water in order to get it into their lungs. They have blow-holes opening like nostrils on the top of the head. The impure air which they breathe out when they come near the surface, carries up water with it, and hence they are said to spout water from their blow-holes. It is their strong breathing which forces up the water of the sea. They have no hair, and a loose skin, under which is usually a very thick layer of oily fat, or blubber. Their fore limbs resemble fins, and their hind limbs are wanting. The tail is broad and flat, and is placed horizontally, so that they strike the water downwards and upwards, and can thus rise easily to breathe, or sink to escape from danger.

The **Greenland** or **common whale** is the largest of known animals. Its length is about eighty feet, and yet it feeds on small molluscs and jelly-fish. It has no teeth; but, instead, has fringes of whalebone hanging round its palate, with which it sifts its food from the sea water. Its milk is not unlike that of a cow; and its fat forms a valuable oil. It nurses its young as carefully, and is as fond of them, as any land animal. The **cachalot**, or spermaceti whale, has a huge head flattened in front; and in it are caves or holes which contain, sometimes, as much as ten barrels of clear oil. This oil crystallises and forms spermaceti. In the body are also got sperm oil and ambergris, or grey amber, which is used as a perfume. The animal has strong teeth in its lower jaw, which fit into holes in the upper jaw, when the mouth is shut. The **narwhal** is chiefly remarkable for its long tusk, ten or twelve feet long, which sticks straight out like a horn, so that the animal is often called the sea-unicorn. **Porpoises** swim about in shoals; have sharp teeth; feed on small fish; and are very voracious. They come up rivers and inlets of the sea, puffing and snorting, and making groaning noises, which lead sailors to say that the porpoise is the only fish which is not dumb. The fact that it can make these noises shows that it is not a fish.

The **Dolphin** is very like a porpoise, and is often called one. Its snout is longer and narrower than that of a porpoise. It is a favourite animal with poets, who often refer to its wondrous changes of colour when it is dying; and, indeed, they are wonderful. The poets also relate many stories about its love for mankind—with not a word of truth in them. The true cetacea all live upon other animals; but there is also a division of the mutilates which eats herbs, chiefly sea weeds; and is therefore commonly spoken of as the **herbivorous cetacea.** To this belong the *sea cow* and the *dugong.* They have fins like paws, but no hind limbs. The sea cow has a long melancholy cry; its head and face have something human in appearance. The female nurses her young at her breast, holding them up with her fins. The flesh, both of the sea cow and the dugong, tastes like beef. These animals have given rise to absurd stories about mermaids or sirens, and they are hence classed distinctly from the whale-like animals, under the name of the siren-like* mutilates.

The section of hoofed animals, or **Ungulates**, contains two orders: **ruminating**† or cud-chewing animals; and **thick-skinned**‡ animals. Their name of hoofed animals shows that they have neither toes nor fingers free. Their limbs serve entirely for support and motion; and the end of each limb is shut up in a hollow horny box, formed of an expanded nail, and called a hoof.

The order of **ruminants**, or cud-chewers, includes very many kinds or genera; all of them useful to mankind, timid in their nature, and eaters of herbs. Their feet are cloven into two hoofs. They have four stomachs. Their food, having been only partially chewed, is swallowed into the first stomach, called the paunch; and from it passes into a second, called the honeycomb. It comes back from this one to the mouth in the form of little round pellets, and is slowly chewed over again. Hence they chew the chewed; or, as we say, the cud. It is swallowed a second time into a third stomach, called the many-plies; and from this it passes into the fourth and real stomach, where it is finally turned into chyle. The name for this process is ruminating; hence that of the order. Most of the ruminating animals are horned; some are not. Those which have *no horns* form the first section of them, including the camel, the lama, and the musk. A second section consists of the animals *whose horns fall off, and are renewed.* Such horns generally grow only on the head of the males, but in some cases females have them too. This section includes the elk, the reindeer, and stags, and roes. A third section with *horns short, abiding, and covered by a hairy skin* is formed by the giraffe. A fourth is formed by those ruminants which have *hollow horns that do not fall off,* and includes antelopes of all kinds, goats, sheep, and oxen.

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* Sirenia. † Ruminantia. ‡ Pachydermata.

Camels are wondrously fitted for travelling in the sandy desert. Their feet are broad; their two toes are united by a padded sole, and are surrounded by hoofs; and their chest, shoulders, and knees have rough hairless pads, upon which they rest when they lie down. They are able to endure a long time without either water or food; and can move with heavy burdens across the desert at the rate of forty or fifty miles a day. They have humps or masses of fat on the back, which seem to be stores of nourishment laid up for times of fasting, like the stores which we have already learnt of in plants. There are two varieties of the camel, the Bactrian camel, with two humps, and the Arabian camel, or dromedary, with only one. The **lamas** are, so to speak, the camels of Central America. They are small, and have no hump. The alpaca goat, a kind of lama, yields a fine wool. The musk is a pretty little hornless ruminant of India, which yields the perfume called musk, from a little bag found *in its belly.*

The **elk** is one of the largest of the deer tribe, that is, of those animals which have branching horns or antlers that are shed yearly. It is about the height of a horse; and is so cunning that it is difficult for hunters to get near it. The reindeer is as famous for its numerous uses to the inhabitants of the foreign zones, as the cocoa nut is for its uses to the people of the tropics. The beautiful white spotted fallow deer; and stags such as the red-deer of the Highlands, as well as the gentle and affectionate roes, are hunted for their flesh, called venison.

The **giraffe** is the tallest of animals, being about 20 feet in height, with very long neck and long fore legs. It is a most gentle animal, and feeds on the foliage of high trees as well as on grass. It has a long hooked tongue, with which it cleverly strips the leaves from off the branches. Its skin is yellowish with dark brown spots.

Antelopes resemble deer in their elegant shape and speed of foot, and also in being able to shed tears. They abound in Southern Africa, and roam about in immense herds. The varieties of them are very numerous. They are often spoken of by poets for the beauty of their large dark eyes. One kind of them, called the gnu, resembles an ox in its horns; and a horse in its limbs and mode of running.

The different kinds of goats, sheep, and oxen are almost endless. Their uses, in yielding food and material for clothing, render them the special friends of man; and, being timid and stupid, they find no small advantage in the struggle for life, from the care with which men breed and rear them.

All the ungulates or hoofed animals which do not ruminate, form the order of **thick-skinned** animals. Their thick skins have few hairs upon them; their gait is heavy; and among them are the largest animals that live on land. There are three sections of them: the *trunked animals*,* like the elephant; the *ordinary thick skins*, such as have no trunk, like the hippopotamus, the pig, the rhinoceros, and the tapir; and the *solid-hoofed* † animals, of which the horse, zebra, and ass, are the only species.

* Proboscidians. † Solipeds.

Elephants inhabit the forests of tropical Asia and Africa, and live in them to the age of upwards of a hundred years. The nose of an elephant projects into a long trunk, with a finger-like part at the end, which forms an excellent organ of touch. With the trunk elephants collect grass and leaves, on which they feed, and suck up water which they afterwards jerk into the mouth; with it too they can lift very heavy weights; while the finely formed point enables them to pick up small objects. Elephants have strong tusks growing out from the upper jaw; and they are hunted down in Africa for the ivory of which these tusks are made. They have large hanging ears; a very thick skin, with a few scattered hairs upon it; and a short slender tail. There are two species of them, the African and the Indian elephant. Wonderful tales of their sagacity are related; and next to the dog, they seem to be the most docile of the lower animals.

The **hippopotamus** lives and swims about in the large rivers of Africa. It has a large heavy body like that of an elephant, but not much of the elephant's sagacity. It feeds on vegetables. The **rhinoceros** has one or sometimes two great horns growing from the skin upon its nose, and seemingly formed of hairs stuck together. It is a stupid clumsy animal. The rhinoceros of Asia has only one horn; that of Africa has two, the one behind the other. The **tapir** is a pig-like animal, with a short trunk at the end of its nose, movable like that of an elephant, but not fitted to lift anything. It is found by river banks in South America and India, and is about the size of an ass.

The **Solid-hoofed** animals have a space between the front and back teeth, into which men slip the bit, by means of which they are able to master and guide them. The zebra of Africa is like the ass in form, and has a yellowish skin, beautifully crossed with black stripes. Wild asses roam about in Central Asia. The length of the asses' ears, and his patience under ill usage, are proverbial. The horse is the most beautiful and most useful of domestic animals.

The third great section of mammals is that of the animals with claws or nails, called the **Unguiculates.** It includes seven orders: *toothless animals; gnawing animals; bats; insect-eaters; flesh-eaters; four-handed animals*, or monkeys; and *man*, the highest of all animals, who forms an order by himself—the order of *two-handed* animals.

The least perfectly organised of them is the order of animals called **toothless**,* from their all agreeing in the character of having no front teeth. There are not many kinds of them, and they almost all inhabit South America. The chief kinds are the *armadillo*, the *manis* or pangolin, the *ant-eater* of Tasmania, and the *sloth*. To these may be added the *porcupine ant-eater* and the *duck-bill*.

The **armadillo** is covered with a solid shelly armour, into which he can draw himself at will. He eats ants; and his strong claws serve him to dig a large hole, in which he passes the greater part of his life. The **manis** has a long, sticky tongue, and his lizard-shaped body is covered with scales, which he can raise on end when he rolls himself up like a ball. The **ant-eater** is not unlike the manis, but in place of scales he has a rather pretty black and white fur. His tongue is hard, long, and gummy. With his snout he makes a hole in the side of an ant-hillock; through this hole he thrusts his tongue; the ants climb on it, are caught, and swallowed. The **sloth** differs from all the other species of ant-eaters in almost everything but the want of teeth. He has enormous claws; climbs trees, eats the leaves, and moves about among the branches most actively; but he walks slowly and painfully on the ground.

The porcupine ant-eater and the duck-bill are classed together under the name of **monotremes.** Although they are mammals and hairy animals, they lay eggs like birds; and, indeed, resemble birds in the structure of some of the internal parts of the body. They are found only in Australia and Tasmania. The **porcupine ant-eater** is covered on the upper part of the body with spines as well as hair, and has a long narrow snout, with a small mouth at the end of it, from which it can thrust a long round tongue. It rolls itself up like a hedgehog when danger is near. The **duck-bill** is a small hairy animal, with a flat tail, short legs, webbed feet, and a bill like a duck. It inhabits holes on the banks of streams and marshes, dives and swims like a duck, and sifts the mud for insects and worms.

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* **Edentates.**

The next order of unguiculates, or animals with claws, is that of the **gnawers** or **rodents**. They have strong chisel-shaped cutting teeth, and can gnaw well with them; hence their name. Among the larger gnawers are the *beaver*, the *porcupine*, the *rabbit*, the *hare*, the *marmot*, the *guinea-pig*, and the *squirrel;* and among the smaller ones are the *rat* and the *mouse.*

Beavers are water animals; about three feet in length from the head to the tail. The toes of their hind feet are joined by a skin, and their tail is flat and scaly. They live in pairs in Europe, but they form large colonies on the rivers of North America. They gnaw down trunks of trees, and form dams by means of them across a stream. On these dams they build their huts. **Porcupines** have their bodies covered with black and white sharp-pointed quills or spines. They feed on bark, and fruit, and young shoots of trees. They are harmless animals. **Squirrels** live on trees; feed on nuts, birds' eggs, and insects in the summer; and sleep through the winter. In Russia and North America there are squirrels which have a skin stretching from the fore to the hind legs, and that keeps them from falling as they leap from tree to tree. These are called flying squirrels.

The next order is that called the **pouched** animals,* and marked by having a pouch formed by a fold of the skin, in which the females carry their young. These young are born in a very weak, helpless state, and during the first part of their lives hang on to teats which are inside of the pouch; and are nourished there. The pouched animals seem to form, as it were, a small sub-kingdom by themselves, and have among them flesh-eating, herb-eating, ruminating, and other divisions. But they are not widely spread over the world. They belong chiefly to Australia; the only ones found out of it are the opossums of America. *Kangaroos* and *opossums* are the two best known kinds.

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* Marsupials.

Kangaroos, in their general figure, are not unlike deer, but they usually stand upon their hind feet; and their tail, which is large and strong, acts as if it were a third leg in supporting them. They are jumping animals—helping themselves in jumping by the tail. Their fore legs are very small. The giant kangaroo can leap about twenty feet at one spring.

The **opossum** of America is about the size of a cat, and has large ears. It moves about at night upon trees, and feeds on birds, insects, and small reptiles. The young of the opossum soon leave their mother's pouch, get on to her back, twine their tails round hers, and thus, keeping firm hold, are carried about by her. When in danger, the opossum, like a spider, lies perfectlv still as if it were dead.

CHAPTER VIII.

MAMMALS.—II.

THE mammals which obtain their food by hunting other animals, or the beasts of prey, as they are usually called, receive from naturalists the name of **Carnars**,* and are divided into three orders: first, **flesh-eaters**,† or hunters of other vertebrated animals; second, **insect-eaters**;‡ and third, **wing-handed**§ animals, such as the bat, which preys upon night-moths, and even, it is said, sucks the blood of sleeping animals.

The **Flesh-eaters** have strong claws and teeth, great quickness of eye, speed of foot, and strength of limb; without which it would be impossible for them to run down and kill the other vertebrated animals upon which they feed. They are commonly arranged into three sections;

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* Carnaria. † Carnivora. ‡ Insectivora. § Cheiroptera.

first, those which walk on the sole of the foot;* second, those which walk on their toes;† and third, those with hind limbs formed into a kind of fin,‡ by means of which they swim.

Among the most important of the **Sole-walking** flesh-eaters are the *bear*, the *badger*, and the *glutton*. The **bear**, although a flesh-eater, is able also to live upon roots and fruit, and is exceedingly fond of honey. In fact, it might more properly be called an eater of any kind of food, than an eater of flesh. In this respect the bears resemble mankind; and in another respect also they resemble mankind more than monkeys do; namely, they can both stand upright, and walk on their hind legs better than any monkey. Bears, however, are heavy, small-eyed, wide-nostrilled, 'and short-legged animals, which live in holes in the trunks of trees, and pass the winter sleeping in such holes. They are found only in mountainous and thinly-peopled countries. The brown bear of Europe, and the black grizzly bear of America, live in forests; the white or polar bear, the largest of the bear kind, catches seals and fish in the icy regions of the north. Their flesh is eaten; their fat is used by perfumers; and their skins make good carriage covers. **Badgers** are much smaller than bears, and like them can live upon fruit. Their bodies are larger behind than before, and their legs are short. Under the tail they have a kind of pouch, from which oozes a thickish fluid, which has a most detestable odour. They live in holes in the ground, from which they come out at night, and prowl about, hunting for rabbits, field mice, and insects. They are hunted for their black and white hairy skin, which is in demand among brush and hair-pencil makers. The **glutton** inhabits North America, and is similar in its habits to the badger. It is hunted for its brown fur.

The two most important divisions of the **Toe-walking** section of beasts of prey are the animals of the *dog*§ tribe, and those of the *cat*|| tribe. After them come the *hyenas*, the animals of the *weasel*[*] tribe; and those of the *civet*[†] tribe.

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* Plantigrade. † Digitigrade. ‡ Pinnigrade. § Canis.
|| Felis.

Among the dog tribe are the *domestic dog*, in all its varieties; the *wolf;* the *jackal;* and the *fox.* These are all so like each other in many respects that they are often spoken of as if they formed one species. The fox differs from the dog, wolf, and jackal, more than they differ from each other. The faithfulness of the dog, the cunning of the fox, and the ferocity of the wolf, have formed the subjects of many an interesting story. The jackal is smaller than a wolf, and prowls about among the ruined cities of Western Asia.

Among the animals of the cat tribe are the *domestic cat*, the *tiger*, the *leopard*, the *panther*, the *lion*, the *cougar*, the *jaguar*, and the *lynx.* They have all claws that can be drawn up within sheaths which are formed by a fold of the skin of the toes, or retractile claws, as they are called. These claws can be very quickly thrust out, however, when the animal wishes to strike at or to hold down its prey. They have a kind of elastic fatty pad under the toes, by means of which they tread very noiselessly, as we can see in the walking of a cat. Their jaws are short and very strong, crunching bones easily; and they can open their mouths very wide. The cat tribe are perhaps the fiercest and most dangerous of land animals; and the bravest and strongest of them is the lion. Brave, however, as it is, it will not attack a man unless pressed by hunger. Its roar spreads terror whereever it is heard; and the thick mane around its head, neck, and shoulders, gives it a majestic appearance, which perhaps has led men to speak of it, and write fables about it, as the king of animals. Its tail—which is usually held up in a graceful curve, but is straightened out behind when the beast is angry—has a bushy tuft at the end of it. The lion is of a tawny colour, and is found only in some parts of Africa and Asia. Fiercer than it, and much more beautiful—with its yellowish skin above, black stripes down the sides, and pure white colour below—is the tiger, the terror of native Indians. **Tigers** are found only in Asia and the Asiatic islands, where they haunt the thick jungles, sleeping in the shade by day, and coming out to seek their prey at night. The **cougar** or **puma**, and the **jaguar** are animals of the New World, which, though not so large as the lion or the tiger, have the same habits and general structure. The **panther** inhabits the warm countries of the Old World. Its skin is of the same colour as that of the tiger, but spotted instead of striped; and furriers call it the African tiger. The **leopard** is coloured and spotted like the panther, but is not quite so large. The **lynx** is a smaller animal than any of these; it inhabits the cold regions of the north, and has a thick valuable fur.

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[*] Mustelidae. [†] Viverridae.

Hyenas differ from animals of the dog and cat tribes, and yet in some respects resemble both. They are like dogs, inasmuch as their claws are short and not sheathed; like cats in their rough tongues and strong jaws, and in the stripes or the spots on their skins. They differ from both, as they have only four toes on their fore feet, and have a stiff mane along the ridge of the back, from head to tail. They live in Africa and the south of Asia, prowling among ruins and tombs, or over battle-fields, where they feast on the bodies of the dead.

The animals of the weasel tribe have long narrow bodies, fitted to pass through small openings. They are small animals, but very cruel foes to all kinds of poultry; and, indeed, to all animals smaller or weaker than themselves. They have a disagreeable smell. One of them, called the **skunk**, is proverbial for its abominable odour. The common **weasel** is the smallest of the kind to which it gives its name; it feeds on rats and mice, and chickens or eggs when it can get them. The little red-eyed white-coated **ferret** is used in hunting wild rabbits. One of this kind, called the **stoat** or **ermine**, lives in Siberia, and is hunted for its fur, which changes from a deep red colour in summer, to white in winter. Another is the **marten**, or **sable**—valuable, too, for its fur. It lives on trees catching birds and squirrels· while the **otter**, which is also included among the weasel tribe lives by river sides, and feeds on fish. The feet of the otter are broad and webbed; its tail is flat, and its fur has two kinds of hair, one long and silky, the other short and woolly. It catches fish with unerring skill, and always comes on shore to eat them. Another of this kind, and perhaps the fiercest of them all, is the **polecat.** It is the terror of poultry keepers, for it kills more than it can eat or carry off.

The animals of the civet tribe are not unlike those of the cat tribe. They have all rough tongues and claws which can be drawn back into sheaths. In the hinder part of the body, some species of them have a pouch which contains a substance used as a perfume. These animals inhabit Africa and the Indian isles. They roam about at night. The common **civet** is about the size of a badger; and one species, called the **ichneumon** or Pharaoh's rat, is famous for its destruction of crocodile's eggs. The ancient Egyptians worshipped it because of this; and the Hindoos keep it for hunting rats and serpents.

The third division of flesh-eaters is that of the **Fin-movers,** which can live both on land and water, and are hence called **amphibious.** These feed upon fish for the most part, and have the hind limbs converted into a kind of tail-fin. The best known of them are the *seal,* and the *walrus* or sea-horse.

The **seal,** though covered with a soft silky fur, has both its fore and hind paws webbed; the hind paws are turned backwards close to each other, with the flat tail between them; so that all three together form an organ like the tail-fin of a fish. Their bodies taper backwards like those of a fish. They have heads like that of a dog, and whiskers like those of a cat. They abound in cold regions; clamber upon the rocks; and move awkwardly on land. They bark like a dog; and are intelligent and affectionate animals. They are hunted for their blubber, and for their skins, which are of great value. Some kinds are only about three feet in length—others five and twenty feet.

The **walrus**, morse, or sea-horse—for it gets all three names—is a larger and heavier animal than the seal, but otherwise is not unlike it. Its body is covered with brownish hair, and its face has projecting bristles, or whiskers. It has two strong tusks in the upper jaw, which help it to lift its unwieldy body out of the water on to the ice of the polar regions, where it lives in herds. It is hunted for its oil, and for the ivory of its tusks.

The **Insect eaters**, which form the next order of the carnars, or beasts of prey, are mostly small and timid animals. They are arranged into three families, of which the *hedgehog*, the *shrew-mouse*, and the *mole*, may be taken as examples. The back of the **hedgehog** is covered with prickly spines; and at the approach of danger it rolls itself up like a ball. The **shrew** is plentiful enough on every farm and river side; and one of its species is the smallest of known mammals—being two and a half inches from the snout to the tip of the tail. The small velvet-furred **mole** forms passages under ground, radiating from a central part. Along these it runs in pursuit of insects. Its body fits it admirably for the work of digging these passages. Its velvet fur lies smoothly in all directions; its nose is long and pointed; and its fore paws are very strong, furnished with stout long nails, and set like hands with the palms turned outwards. In digging, the earth is thrown behind it, and thus does not interfere with its progress underground. The mole has very small eyes, but it is not blind—as worms and grubs learn to their cost. Its senses of hearing and smell are very acute.

The last order of the carnars, or beasts of prey, is that of the so-called **wing-handed animals**, better known as bats. Their scientific name, meaning wing-handed, is given them from the fact that a skin or membrane joins the neck to the enormously long claws or fingers of their fore limbs, stretches between each of these claws or fingers like the silk of an umbrella between the ribs; and then from the last of the claws of the fore limb it stretches along the sides to the hind limbs, and in some kinds of bats from the hind limbs to the tail. This membrane thus forms two skinny wings, one on each side. These wings can be easily folded up by the animal bringing the long fingers together, and its arms—so to speak—close to its sides. The bat is a night-flying animal. During the day it hangs on by its hooked thumb to walls in dark places, and comes out at night to chase moths. Some kinds have very large shell-shaped ears, and some have skins surrounding their noses in horse-shoe or other fanciful shapes. What help these skins give them in the battle of life, it would be hard to say. There are bats in the tropical regions, called vampire bats, which are said to suck the blood of men whom they find asleep, and also of other animals. In Japan, a bat with a body as large as that of a cat hangs itself from the branch of a tree, by its hind claws, during the day; and as there is usually a large number hanging upon the same tree, they seem like some strange fruit. As winter comes on, bats like many other animals hybernate; that is, they go to sleep, not for a night, but for a whole season, in the most retired places to be found, an old church, a ruin, a cave; and there they hang—dreaming probably of summer evenings, and the pleasures of a feast of moths. There are above twenty different species of bats in Britain.

The highest of all the orders of mammals, if we exclude mankind, is that formed by what are called the **four-handed** animals—better known as monkeys. A hand, of course, is not a foot; and the difference is—that there is in the hand one of the fingers, or rather digits, which can be opposed to, and pressed against the others, as we can do with our thumbs. In a foot there is no such digit; we cannot close our great toe upon the other toes of the same foot, and so catch or hold things. In the four-handed animals, or monkeys, their hind limbs as well as their fore limbs end with hands. These hind and fore limbs, since they end in hands, are really fore and hind arms. Whether we call them legs or arms, monkeys walk upon them; but not upon the two hind ones only, except with great difficulty; and not at all uprightly. Like mankind, monkeys have their eyes in the front of the head, and teats on the breast. They live in woods and sleep for the most part on trees, on which some of them build a kind of nest. They are hairy animals, but some of them have parts of their bodies bare, and with thickened skins, called callosities. They get along on the ground by jumping rather than by walking. Many have pouches in their cheeks, opening into the mouth, in which they store food. Some have no tail; others have a very long one, with which they can grasp objects, as if it were a fifth hand. Such a tail is said to be prehensile.

The lowest division of the four-handed animals is marked by twisted or *curved nostrils*, placed at the end of a snout like that of a fox; another division has the *nostrils opening outwards* at the side of the face, and widely apart; the third and highest division has the *nostrils opening downwards*, as mankind has, with only a very thin partition between them. These three divisions or families are named by words which mean **curve-nostrilled**,* **flat-nostrilled**,† and **descending-nostrilled**.‡ The animals of the first family are found only in Madagascar and the neighbouring islands; those of the second form the monkeys of the New World; those of the third inhabit Africa and Asia.

The most important kinds of the **curve-nostrilled** family of four-handed animals are the *aye-aye* and the *lemurs*. The aye-ayes have some resemblance to squirrels; the lemurs are about the size of cats, and not unlike them, except the fox nose. They have long prehensile tails. There is a species of lemur which has a skin stretching between the fore and hind legs and on to the tail. This enables it to take long sweeping leaps from tree to tree, and almost to fly.

Among the **flat-nostrilled** South American monkeys are the *howling monkeys*, which make the forest resound with their yells; and the *spider monkeys*, with round flat bodies, very long limbs, and gripping tails. These live in troops; and cross a river, it is said, by a number of them mounting a high tree on the bank—one grasps the tree;

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* *Strepsirhines.* † Platyrhines. ‡ Catarhines.

another grasps this one's tail; a third the tail of the second; a fourth that of the third; and so on, forming a long chain which the one holding the tree swings like a pendulum, till at last it is swung across to the trees on the other bank, one of which the last monkey catches; the first then lets go its hold, and all are drawn over. It is said that they fish for crabs with their tails. They are easily tamed, and very docile.

Among the **downward-nostrilled** family are the *sacred monkey* of the Hindoos; and the kind called *macaques*, with short tail and projecting muzzle. It is this kind which is found on the rock of Gibraltar, and is the only wild monkey in Europe. In this family, too, are the *baboons*—large and strong animals, with little or no tails. One of them, called the *mandril*, is about the height of a man. It is also in this family that those monkeys are found, of which naturalists who are fond of hypotheses assert, that either from some of them, or from species which were their ancestors, mankind is descended. These are called the man-like* apes. Among them are the *gibbon*, or long-armed ape of Asia and the Indian Archipelago, covered with a thick fur; the *orang*, of Sumatra and the neighbouring islands, also very long-armed, but short-legged; and the *chimpanzee* of Western Africa, with arms reaching to the knee, hands that are clear of hair, and a queer, wrinkled, old mannish face. But the most famous of them all is the redoubtable *gorilla*, nearly the size of a man—a strong ferocious animal which walks on his two hind arms by the help of a branch held in the hands of his two fore ones; and beats his breast and roars fiercely on the approach of a stranger to his lair. If humanity consist in walking by the aid of branches, beating the breast and howling, then, undoubtedly, the gorilla is a very man-like ape.

Man, considered as an animal, is placed in a separate order of the mammalia, called the **two-handed.**† But there are so many things which distinguish him from all other livings beings, that it is hardly to be wondered at

* Anthropoid. † Bimana.

if some refuse to include mankind in a description of the animal kingdom. Man alone has two hands and two feet, and the power to walk upright. His hands are thus set free to carry out the suggestions of his intellect. Man alone has a voice which is used for distinct speech, and the freedom which he thus gains for his hands, compared with what he should have had, had he been compelled to use a language of signs, is of great advantage to him in the struggle for life. These, and other advantages arising from his bodily structure, render him indeed the paragon of animals; but man is especially distinct from and above all the rest of the animal kingdom by his intellectual and moral perceptions, and by his religious feelings. He alone reasons, and knows why he does what he does, while all other animals are guided in their acts by blind instinct. He alone possesses what can properly be called a sense of right and wrong. He alone among living beings looks forward to another life beyond the grave; recognises the existence and feels the presence everywhere of an Infinite Creator, to whom he is responsible for all his acts; and recognises also the goodness and the power of that Creator in all the wondrous arrangements of the different kingdoms of Nature.

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